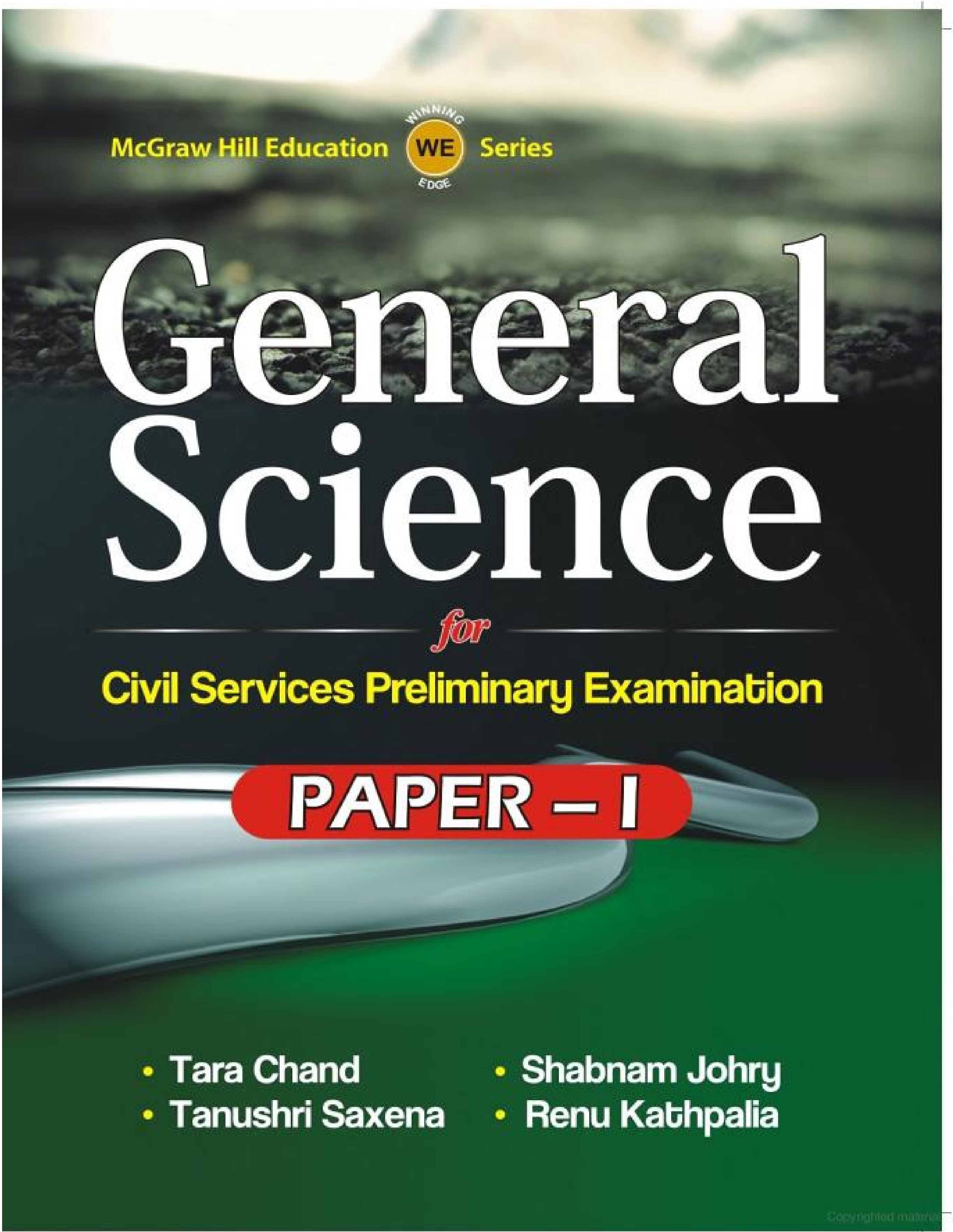

McGraw Hill Education WE Series

General Science

for

Civil Services Preliminary Examination

PAPER – I

- Tara Chand
- Shabnam Johry
- Tanushri Saxena
- Renu Kathpalia

TATA McGRAW-HILL'S WINNING WE EDGE SERIES

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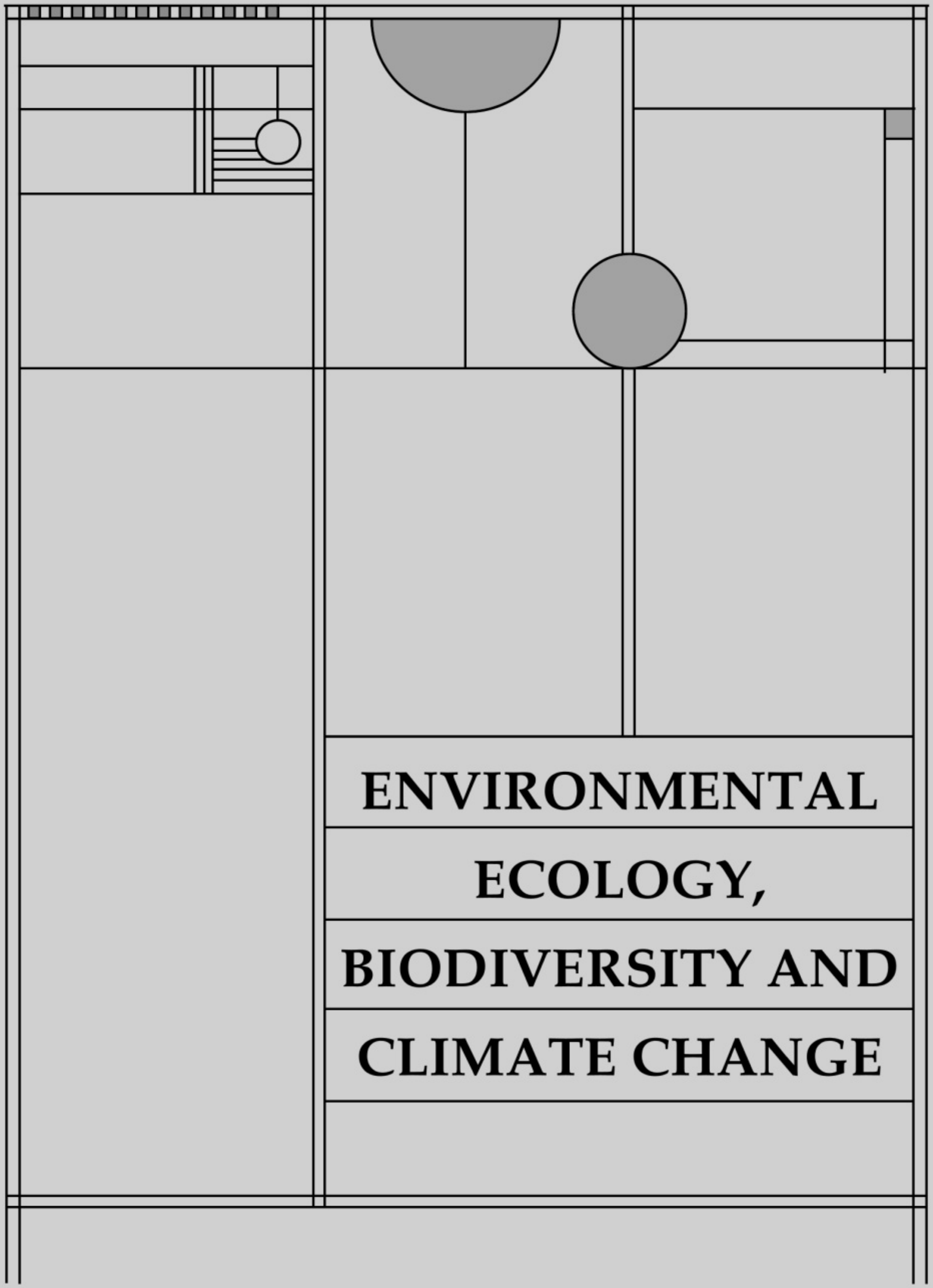


ENVIRONMENTAL ECOLOGY, BIODIVERSITY AND CLIMATE CHANGE

CHAPTER ONE

BIODIVERSITY: THE BIOLOGICAL PERSPECTIVE

A.1.1 INTRODUCTION

The biosphere is a global ecosystem. It includes the entire portion of the earth inhabited by life. In a broader sense, biospheres are any closed, self-regulating systems. The term **"biosphere"** was coined by geologist Eduard Suess in 1875. He defined biosphere as *the place on earth's surface where life dwells*.

The biosphere's ecological context came from 1920s, preceding the 1935 introduction of the term **"ecosystems"** by Sir Arthur Tansley. Valdimir I.Vernadsky defined ecology as the science of the biosphere. It is an interdisciplinary concept for integrating astronomy, geophysics, meteorology, biogeography, evolution, geology, geochemistry, hydrology and all life and earth sciences. The biosphere is a core concept within biology and ecology. Ecology provides a scientific context for evaluating environmental issues. To address environmental problems, we need to understand the interaction of organisms and their environment. The science of ecology provides that understanding. It is important to communicate the scientific complexity of environmental issues.

A.1.2 ECOLOGY

Ecology is the scientific study of the rich and varied interactions between organisms and their abiotic environment. In ecological studies, the environment encompasses both **abiotic** (such as water, mineral nutrients, light, temperature) and **biotic** factors (living organism). Interactions between organisms and their environment is a two way process in which organisms influence and are influenced by their environment. There are many reasons to care about ecology. Our lives are enriched by the fascinating interactions between the organisms. Watching a butterfly visiting a flower and bringing about pollination is worth seeing. Beyond simple curiosity, information from ecological sciences is needed to solve many practical problems. An understanding of ecology allows us to grow food, control pests and diseases and deal with natural disasters such as flood, drought and earthquake.

A.1.3 BRANCHES OF ECOLOGY

1. Ecology and Evolution

Ecology and evolution are considered sister disciplines of the life sciences. Natural selection, life history, development, adaptation, populations and inheritance are examples of concepts that correlate equally into ecological and evolutionary theory.

(a) Behavioural Ecology This is the study of animal behavior in the natural environment, also known as **ethology**. Behavioural ecology also deals with ecological and evolutionary changes, because of the interactions among the organisms. Adaptation is the central unifying concept in behavioural ecology. The behaviours evolve and become adapted to the ecosystem because they are subject to the forces of natural selection. Consider the edible beetles that direct sprays of poisonous chemicals at their attacker. Predator-prey interactions are an introductory concept in behavioral ecology.

(b) Social Ecology This is concerned with the relationships between organisms and their environment. Social ecological behaviours are notable in the social insects, slime molds, social spiders and human society. Individuals that belong to a social group have to face competition for food, mates and other limited resources. They face diseases and parasitic infections. A special kind of behavior exists between many groups. This is known as **altruism**. (Behavior that harms the individual who performs it but benefits other individuals.) through genetic relationship. Parenting is also altruism, where the children are benefited. Altruism is extreme among some insect societies, such as honeybee and termite colonies. Groups that are predominantly altruists beat groups that are predominantly selfish.

(c) Co-evolution Populations of the other species are part of any organism's environment. The population having prey-predator interactions exert pressure on each other. If prey evolves, the predator counter develops mechanisms to catch the prey. This is the basis of co-evolution in populations. There are many examples where interacting organisms evolve together e.g., lithops (flowering stone) growing in the open area develop stone like pattern and color to hide from herbivores.

(d) Bio-geography This is the comparative study of the geographic distribution of organisms and the corresponding evolution of their traits in space and time. Bio-geographical processes that result in the natural splitting of species explain modern distribution of the earth's biota (flora and fauna).

2. Molecular Ecology

Molecular ecology a relatively new field where the important relationship between ecology and genetic inheritance is analysed using modern techniques of molecular analysis. Molecular ecological research became more feasible with the development of rapid and accessible genetic technologies, such as the polymerase chain reaction (PCR). The DNA of different organisms is compared and their evolutionary relationships are analysed.

3. Human Ecology

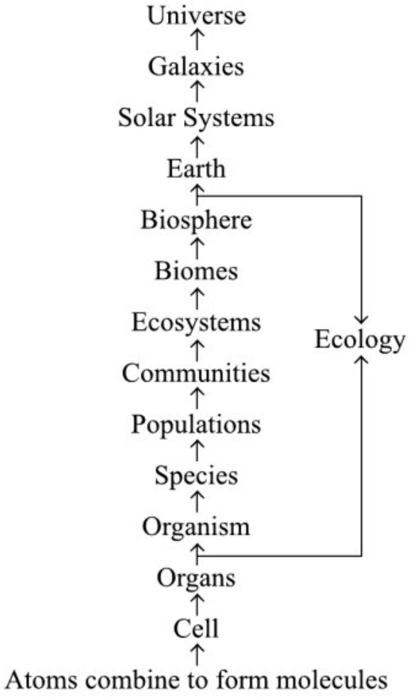
Human ecology is the interdisciplinary investigation into the ecology of our species. It is the discipline that inquires into the patterns and process of interaction of humans with their environment. It studies human values, life styles, resource use, waste etc. The human species is not an external disturbance. It is the keystone species within the system.

4. Landscape Ecology

Landscape ecology is a sub discipline of ecology that studies ecological processes that operate over large areas. A landscape ecologist examines the connections among ecosystem found in a particular region.

A.1.4 THE HIERARCHICAL STRUCTURE OF ECOLOGICAL SYSTEM

The different levels of biological organisation include:



The characteristics of molecules and their organization in a cell up to speciation are discussed in the biology section. This chapter includes interaction at population and the levels above it.

Population Ecology

Population is a group of organisms of the same species that live in the same area at the same time. Certain principles govern the growth and sustainability of populations over time. Ecological interactions start within and between populations.

Each population has its own gene pool and range of traits. It also has a characteristic size, density, distribution pattern and age structure. Environmental conditions and species interactions influence these characteristics. Population size is generally an outcome of births, deaths, immigration and emigration.

As long as the per capita birth rate remains even slightly above per capita death rate, a population can grow exponentially. Resources in short supply put limits on the growth of population. The maximum number of individuals of a population that can be sustained indefinitely by the resources in a given environment is referred as **carrying capacity**. The number may rise or fall with changes in resource availability. The size of a low-density population may increase gradually; go through a rapid growth phase, then levels off once the carrying capacity for the population is reached. The limiting factors vary in their relative effects and vary over time, so, population size also changes over time. Limiting factor such as competition for resources, disease and predation are density-dependent. Density-independent factors, such as weather on the rampage, tend to increase the death rate or decrease the birth rate more or less independently of population density.

Community Ecology

Community is a natural association that consists of all populations of different species that live and interact within an area at the same time. These interactions in turn influence the structure of communities. The many ways in which organisms interact with one another are as following:

Symbiosis Any intimate **relationship** or association between members of two or more species. Symbiosis is the result of co-evolution. Flowering plants and their pollinators have a symbiotic relationship.

- **Parasitism:** Interactions in which one organism is harmed, but the other benefits. A parasite may weaken its host; it rarely kills its host. More than 100 parasites live in or on the human species. When it causes a disease and sometimes the death of host, it is known as **pathogen**. Crown gall disease, caused by a bacterium, occurs in many plants.
- **Mutualism:** Interactions in which both participants are benefited. The interdependent association between nitrogen fixing bacteria of the genus *Rhizobium* and legume, is an example.

Another example is the association between reef building coral animals and microscopic algae. The symbiotic alga is called **zooxanthellae**. **Mycorrhizae** is such an association between fungi and roots of 80% plants.

- **Commensalism:** Interactions in which one participant benefits but the other is unaffected, e.g., relationship between two insects; silverfish and army ants, relationship between a tropical tree and many epiphytes, smaller plants, such as mosses, orchids and ferns that live attached to the bark of the tree's branches. The epiphytes anchor itself to the tree to obtain adequate light and water and not for obtaining nutrients from the tree.

Predation **Predator-prey interactions** typically undergo oscillations. As predator population grows, they may eat most of their prey; the predator population then crashes. **Mimicry** is an adaptation by prey to predation. Plants possess adaptations that protect them from being eaten such as the presence of spines, thorns, tough leathery leaves or thick wax on the leaves. Other plants produce protective chemicals that are toxic to herbivores. Animals also have adaptation to protect themselves from being eaten. Some animals blend into their surroundings to hide from predators. Besides warning coloration and chemical defenses, some animals live in herds to protect themselves.

Competition Interactions in which two organisms use the same resources, and those resources are insufficient to supply their combined needs, is called competition. Competition invariably results in a reduction in the number of one or both competitor.

Amensalim Interactions in which one participant is harmed but the other is unaffected. For example, the shading out of one plant by a taller and wider one; the inhibition of one plant by the secretions of another (known as **Allelopathy**).

Ecosystems

A community and its physical environment is called its Ecosystem. An ecosystem is a biological environment consisting of all the organisms living in a particular area, as well as all the non-living (abiotic), physical components of the environment with which the organisms interact, such as air, soil, water and sunlight.

Ecosystem is an open system with inputs, internal transfers and outputs of energy and nutrients. Sunlight is the initial energy source for nearly all ecosystems. The different types of ecosystems are

(i) Natural Ecosystem
  (a) Terrestrial ecosystem
  (b) Aquatic ecosystem
  (c) Lentic (lake, pond or swamp)
  (d) Lotic (river, stream or spring)
(ii) Artificial Ecosystems

The species that live and interact in an area constitute an ecological community. Ecological communities are loose assemblages of organisms. The organisms in a community can be divided into trophic levels (the position of an organism in food chain) based on the source of their energy. **Primary producers** get their energy from sunlight. **Herbivores** that get their energy by eating primary producers are **primary consumers**; organisms that get their energy by eating herbivores are **secondary consumers;** and so on. A sequence of interactions in which a plant is eaten by a herbivore, which in turn eaten by a secondary consumer, and so on, is known as **food chain**. Food chains are usually interconnected to make a **food web** because most species in a community eat and are eaten by more than one species. Most communities have three to five trophic levels. Energy and biomass decreases as it flows from lower to higher trophic levels and thus can be represented in the form of pyramid. Most of the energy ingested by organisms that is converted to biomass is eventually consumed by **decomposers.**

Ecological pyramids An important feature of energy flow is that most of the energy going from one trophic level to the next, in a food chain and food web, dissipates into the environment as a result of the second law of thermodynamics. Ecological pyramids often graphically represent the relative energy values of each trophic level. There are three main types of pyramids—a pyramid of numbers, a pyramid of biomass and a pyramid of energy.

Ecosystem productivity The **gross primary productivity (GPP)** of an ecosystem is the rate at which energy is captured during photosynthesis in a given period of time. In addition, a plant respires to provide energy for its own use; this acts as a drain on photosynthesis. Energy in plant tissues after cellular respiration has occurred is **net primary productivity (NPP)**. Both GPP and NPP are expressed as energy per unit area per unit time. Humans consume (32%) far more of earth's resources than any other of animal species. If we want our planet to operate sustainably, we must share terrestrial photosynthetic product with other organisms.

In environments that show variations in salinity, temperature and other environmental conditions, food webs tend to have short chains. In stable environments, such as parts of the deep ocean, food chains are longer. In addition to energy inputs, primary productivity and ecosystem structure require a cycling of nutrients. Water and minerals move slowly through the physical environment, rapidly through organisms, and back to the environment in **biogeochemical cycles**. Water moves through a hydrological cycle. In land ecosystems, plants stabilise soil and minimise nutrient loss during the cycle as runoff. In atmospheric cycles, a nutrient prevails mainly in gaseous form (such as carbon, in carbon dioxide). In the carbon cycle, carbon dioxide is the main gas in the atmosphere. The ocean is carbon's main reservoir. Burning of fossil fuels, logging and conversion of natural ecosystems for farming disrupt the global carbon budget and may be responsible for global warming.

Nitrogen is a limiting factor in the total net productivity of ecosystem on land. Gaseous nitrogen is abundant in the atmosphere. **Nitrogen–fixing bacteria** convert N_2 to ammonia and nitrates, which producers take up. **Mycorrhizae** and root nodules, two symbiotic interactions, enhance the nitrogen uptake. Sedimentary cycles interact with the hydrological cycle to move mineral nutrients to and from ecosystems.

Certain human activities are depleting minerals from ecosystems, as when weathered soil of tropical forests is cleared for agriculture.

Some human activities are accelerating the process of **eutrophication**. They are adding nutrients such as nitrates and phosphates to aquatic ecosystems. This promotes growth of destructive **algal blooms**. The excessive growth of plants leads to the depletion of oxygen in the water, which threatens fishes and other animal populations.

Biomes

Some parts of the earth have more or less the same kind of abiotic and biotic factors spread over a large area, creating a typical ecosystem over that area. Such major ecosystems are termed as biomes.

An ecologist recognises a number of large ecological units called biomes, which are based on the growth forms of the dominant vegetation. The distribution of terrestrial biomes is determined primarily by temperature and precipitation, but is also influenced by soil fertility and fire. Each biome is more or less isolated by oceans, mountain ranges or desert barriers. This geographical isolation tends to restrict gene flow between these biomes. As a result, each biome maintains a characteristic species of living organisms.

Terrestrial Biomes Seven categories of the earth's major biomes arranged by distance from the equator are listed below.

1. **Tropical rain/evergreen forest** occur near equator, receive an enormous amount of rain year round, temperature ranges between 25°C–29°C year round and are characterised by the growth of tall trees and lush vegetation. Animal diversity is highest in tropical forests.
2. **Savannas** (hot deserts) also lie near the equator but experience lesser rain than tropical rain forests and sometimes have prolonged dry spells. Savannas are characterised by open grasslands with scattered trees and shrubs.

3. **Deserts** (Cold Desert) are extremely dry biomes; hot deserts are hot year round, whereas cold deserts are hot only in the summer. Deserts are of great biological interest due to the extreme behavioral, morphological and physiological adaptations of plants and animals that live there.
4. **Temperate grasslands** receive less rainfall than savannas but more than deserts; the soil in temperate grassland is rich, so they are well suited to agriculture. Large grazers and burrowing mammals are native to temperate grasslands.
5. **Temperate deciduous/broadleaf forests** receive moderate precipitation that is well distributed throughout the year. The climate of temperate deciduous forests differs from tropical forests as they receive less rainfall, are found at higher and cooler latitudes and experience cold winters. The trees in temperate deciduous forests lose their leaves and remain dormant throughout the winter. It has vertical layers including a closed canopy, one or two strata of understory trees, a shrub layer and an herbaceous layer. In the northern hemisphere, many mammals in this biome hibernate in the winters, while bird species migrate to warmer climates.
6. **Taiga** is the coniferous forest of the north. It is the largest terrestrial biome on earth. The taiga consists primarily of cone-bearing evergreen trees, which are able to survive long cold winters and low levels of precipitation. These forests are home to many birds and mammals. These forests are being logged at a very high rate and old-growth stands of conifers may soon disappear.
7. **Tundra** Even farther north than the taiga is the tundra, which covers about 20% of the earth's land surface and consists largely of open grassland, often boggy in summer, which lies over a layer of permafrost-soil whose water is permanently frozen. Alpine tundra is found on high mountain-top at all latitudes. The arctic tundra winter is long and cold, while summer is short and mild. The growing season is very short. Tundra vegetation is mostly herbaceous consisting of mixture of lichens, mosses, grasses, dwarf shrubs and trees. Migratory birds use arctic tundra extensively during the summer as nesting grounds. Arctic tundra has recently become the focus of significant minerals and oil extraction.

Aquatic Biomes Water provinces cover more than 72 per cent of the earth's surface. They include standing fresh water (such as lakes), running fresh water (such as streams), as well as the ocean and seas around the world. All **aquatic ecosystems** show gradients in light penetration, water temperature, salinity and dissolved gases. These factors vary daily and seasonally. Thus the primary productivity also varies in the aquatic ecosystems. Estuaries, intertidal zones, rocky and sandy shores, tropical reefs and regions of the open ocean are major **marine ecosystems**. **Estuaries** are the areas where freshwater streams or rivers merge with the ocean. The mixing of water creates a unique ecosystem. Microflora like algae, and macroflora such as seaweeds, marsh grasses and mangrove trees (only in the tropics) can be found here. **Coral Reefs** are widely distributed in warm shallow waters. They can be found as barriers along continents. Besides corals, several species of micro-organisms, invertebrates, fishes, sea urchins, octopuses and sea stars also reside in the coral reefs. Photosynthetic activity is greatest in shallow waters and in regions of upwelling. Upwelling is an upward movement of deep, cool ocean water that often carries nutrients to the surface.

Biosphere

The biosphere includes the earth's water, the lower atmosphere and the uppermost portions of its crust in which organisms live. Energy flows one way through the biosphere and materials move through it on a grand scale to influence ecosystems everywhere. The distribution of species through the biosphere is an outcome of the earth's history, topography, climate and interactions among species. The average weather conditions, including temperature, humidity, wind velocity, cloud cover and rainfall over time tells the climate. Climate variation are due to differences in the amount of solar radiation reaching equatorial and polar regions, the earth's daily rotation and annual path around the sun, the distribution of continents and oceans and the elevation of land masses. Interacting climatic factor produce the prevailing winds and ocean currents, which shape global weather patterns. The weather affects soil composition and water availability, which affects the growth and distribution of primary producers in the ecosystems.

A.1.5 BIODIVERSITY

Biodiversity refers to the variety and abundance of living organisms living in a particular region. It has a magnitude that is beyond any limit. The exact number of species present at a global level is still ambiguous. The number may vary from 10 to100 million, and is a product of 4 billion years of evolution. The term biological diversity was used first by wildlife scientist and conservationist **Raymond F. Dasmann** in the year 1968. He wrote a book "*A Different Kind of Country*" advocating conservation. The term biological diversity was contracted to biodiversity; it was coined by W.G. Rosen in 1985. Biodiversity is not easy to quantify precisely but various ecological indicators, such as, number of species in a given area are used to quantify different aspects of biodiversity. It is important for organism interactions and each plays a role in the web of life. Biodiversity is very crucial for human survival. Although it is late, people now value biodiversity for many reasons:

- Humans depends on other species for food, fiber and medicine.
- Species are necessary for the functioning of ecosystems and the many benefits and services those ecosystems provide to humanity.
- Humans derive enormous aesthetic pleasure from interacting with organisms.
- Extinctions deprive us of opportunities to study and understand ecological relationships among organisms.
- Living in ways that cause the extinction of other species is a huge loss since those species have intrinsic value.

Traditionally, three main levels of biodiversity are identified.

(i) Genetic diversity
(ii) Species diversity
(iii) Ecosystem diversity

An additional level has been recently added, i.e.,

(iv) Molecular diversity

Ecosystem and Biodiversity

The ecosystem processes are controlled by diversity and types of the plant, animal and microbial species living within a community. Biodiversity boosts ecosystem productivity where each species, no matter how small, has an important role to play. For example, a large number of plant species means a greater variety of crops; greater species diversity ensures sustainability for all life forms; more sustainability means healthy ecosystem; a healthy ecosystem can withstand and recover from disasters.

"At least 40% of the world's economy and 80% of the needs of the poor are derived from biological resources. In addition, the richer the diversity of life, the greater the opportunity for medical discoveries, economic development and adaptive responses to such new challenges as climate change."- The Convention about Life on Earth.

Human modifications to the living community and collective biodiversity of the earth can alter an ecosystem. The change in ecosystem will change the ecological functions. A healthy biodiversity provides a number of natural services for everyone that are vital to the well-being of human societies.

Ecosystem services

(i) Soil formation and prevention of soil erosion
(ii) Nutrient recycling and storage

(iii) Protection and conservation of water resources
(iv) Pollutants breakdown and absorption
(v) Climate stability
(vi) Maintenance of ecosystems
(vii) It provides biological resources, such as
  - Food
  - Medicinal resources and drugs
  - Wood products
  - Ornamental plants
  - Breeding stocks, population reservoirs
  - Diversity in genes
(viii) It has social benefits
  - Research, education and monitoring
  - Tourism
  - Cultural values

There is long list of ecosystem services we got for free.

As an example, consider all the species of animals and organisms involved in a simple field used in agriculture. As summarised from Vandana Shiva's *Stolen Harvest* (*South End Press*, 2000) pp 61–62;

(i) Crop byproducts feed cattle
(ii) Cattle feeds the soil that nourish the crops
(iii) Crops, as well as yielding grain also yield straw
  - Straw provides organic matter and fodder
  - Crops are food sources for humans and animals
(iv) Soil organisms also benefit from crops
  - Bacteria feed on the cellulose fibers of straw that farmers return to the soil
  - Amoebas feed on bacteria making lignite fibers available for uptake by plants
  - Algae provide organic matter and serve as natural nitrogen fixers
  - Rodents that bore under the fields aerate the soil and improve its water holding capacity
  - Spiders, centipedes and insects grind organic matter from the soil and improve its water holding capacity
  - Spiders, centipedes and insects grind organic matter from the surface soil and leave behind enriched droppings
  - Earthworms contribute to soil fertility
    (a) They provide aerage, drainage and maintain soil structure
    (b) The earthworm is like a natural tractor, fertilizer factory and dam combined
(v) Industrial-farming techniques would deprive these diverse species of food sources and instead assault them with chemicals, destroying the rich biodiversity in the soil and with it the basis for the renewal of the soil fertility.

The available evidences have identified the following certainties concerning biodiversity and ecosystem functioning:

1. Human impact on global diversity has been dramatic, resulting in losses in global biodiversity at all levels, from genes and species to the entire ecosystem;
2. Local declines in biodiversity are even more dramatic than global declines, and the beneficial effects of many organisms on local processes are lost before the species become globally extinct;
3. Many ecosystem processes are sensitive to declines in biodiversity;
4. Changes in the identity and abundance of species in an ecosystem can be as important as changes in biodiversity in influencing ecosystem processes.

Biodiversity and Human Health

Ecosystem provides the life support systems for all life; in addition to that, it purifies air and fresh water, binds and detoxifies poisonous substance, breaks down wastes and recycles nutrients on land and in the oceans, pollinates the crops and natural vegetation, makes soil fertile and stores carbon.

- *Biodiversity supports food security, dietary health and livelihood sustainability*:

Ecosystem provides the foundation of crop development and food security and promotes resistance and resilience to environmental stresses including pests and diseases of crops and livestock. Diets based on a diversity of food species promote health and can help to protect against disease by addressing the problem of micronutrients and vitamin deficiencies. Loss of agricultural biodiversity can therefore threaten health, livelihood sustainability and our future security of food and nutrition.

- *Biodiversity provides important resources for medical research*: Study of wildlife anatomy, physiology and biochemistry can lead to important developments in human medicines. Examples of species of interest to medical science include bears (for insights into osteoporosis, cardio-vascular disorders, renal disease and diabetes), sharks (osmoregulation and immunology) and crabs (ophthalmology and molecular cell biology).
- *Biodiversity provides important resources for traditional and modern medicine*: Modern drugs from wild species include *Inter alla* pain killer (Zinconitide from cone snail toxin), cardiac drugs (Lanoxin from *Digitalis* plants) and treatment for diabetes (Exanitide from lizards).
- *Biodiversity plays a role in the regulation and control of infectious diseases*: In recent years, outbreak of SARS, ebola, avian influenza and malaria have been attributed to human impacts on biodiversity, the wildlife trade or unsustainable land use change.
- *Biodiversity has social, cultural and spiritual importance within the communities*: An awareness of environmental values and respect for other species has been associated with reduced propensity towards anti-social behaviour in children and young adults. An access to 'green space' is associated with better health outcomes than in purely urban environments.

Biodiversity and Economics

In July 2010, the first Global Biodiversity Symposium in London explored the role of biodiversity in business opportunities and risks. Industry is broadly interested in the judicious use of natural resources with operational profitability, without adversely affecting biodiversity. *Biodiversity is fundamental to economics*. The G8 nations, together with 5 major emerging economies (China, India, South Africa, Brazil and Mexico) use almost three-quarters of the earth's bio-capacity. An estimated 40% of world is dependent on biological products or processes.

Biodiversity and Agriculture

About 80% of human's food supply comes from just 20 kinds of plants; humans use at least 40,000 species for food, shelter and clothing. Crop diversity aids recovery when the dominant cultivar is attacked by a disease or predator. In the past, *Irish Potato blight* of 1846 was due to plantation of two potato varieties, 6,273 varieties were screened for resistance to rice grassy stunt virus; only one resistant Indian variety was selected and crossed with other varieties. **Monoculture** was a contributing factor to several agricultural disasters. Bees provide enormous benefits for humankind and agriculture. It is the primary species that fertilizes food producing plants. The interdependence between bees, human and agriculture is very crucial as summarised by researchers.

"Human kind needs to act quickly to ensure the ancient pact between flowers and pollinators stay intact, to safeguard our food supply and to protect our environment for generations to come. These efforts will ensure that bees continue to provide pollination and that our diets remain rich in fruits and vegetables, we now take for granted." (Diana Cox-foster and Dennis van Engelsdrop, *Solving the Mystery* of *the Vanishing Bees*, Scientific American, April 2009.)

Biodiversity and Sustainable Development

Sustainable development is a way of resource use to meet human needs while preserving the environment, so that the resources are available for the generations to come. It is often described as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development has three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability. There is an urgent need for developing a set of guiding principles for sustainable use of biological biodiversity. These principles should be adapted to different human societies and biomes and thus open to modification and improvement as per need. Through an adaptive and ongoing process of this kind, it is possible to maximise the chances that use of biological biodiversity will be sustainable in the long term. It is necessary that civil society and governments understand that sustainable use is a prerequisite for the achievement of the broader goal of sustainable development.

Threats to Biodiversity

Habitat destruction The tropical rain forest destruction is mainly due to habitat destruction. The causative factors responsible for habitat destruction are:

- **Overpopulation:** It is a condition where an organism number exceeds the carrying capacity of its habitat. This term is used for human population. Overpopulation is the ratio of population to available sustainable resources.
- **Deforestation:** It is the removal of a forest and the land is used for other purposes. It leads to multiple environmental problems at atmospheric, hydrological and soil level which ultimately affect the biodiversity. It causes extinction of many species.
- **Pollution:** It is the entry of contaminants into the natural environment. These contaminants cause instability, disorder and harm to the ecosystems or living organisms. The different forms of pollution are air, light, littering, noise, soil, water, thermal, radioactive and visual.
- **Global warming or climate change:** The effect of global climate change and its impact on biodiversity is discussed later in this chapter.

Introduced and invasive species Foreign species introduced from other areas often compete with the local species or their niche may overlap. This competition sometimes results in loss of original or endemic species, because the newcomer may out-compete the native species. Islands are most susceptible to such invasions. At present, several countries have already imported many exotic species, particularly agricultural and ornamental plants that their own indigenous fauna/flora may be outnumbered.

Genetic pollution This term is used for uncontrolled gene flow into wild populations. This process alters the genetic pool. Endemic species can be threatened with extinction through the process of genetic pollution; uncontrolled hybridisation, genetic modification through genetic engineering and genetic swamping are the main factor responsible for genetic pollution. Some degree of gene flow is normal adaptation, but hybridisation with or without check on gene flow threatens a rare species existence.

Overexploitation Overexploitation occurs when a resource is consumed at an unsustainable rate. This occurs on land in the form of overhunting, excessive logging, poor soil conservation in agriculture and the illegal wildlife trade. The international trade of endangered species is almost equivalent to drug trafficking.

Climate change Global warming is a major factor in the loss of biodiversity. Climate change impacts will be more significant in the coming decades. The ice in the Arctic region thaws and refreezes each year, but the pattern has changed in the recent years. In terms of biodiversity, the ice free summers in the

Arctic oceans implies the loss of ocean life. Coral reefs will be lost in 20–40 years if global warming continues at the current rate.

Overpopulation From 1950 to 2011, world population has increased from 2.5 billion to 7 billion.

Patents Intellectual Property Rights (IPR's) and patents have become a matter of concern; megamerger of multinational companies in monopolisation of various life forms and biological resources are becoming a major threat to biodiversity. WTO agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) was negotiated. Article 27.3(b) relates the provisions of TRIPS to biodiversity. It envisages the protection of plant varieties either by patents or by effective Sui Generis (unique or of its own kind) system or by a combination thereof. The two main issues involved being the patenting of life forms and the protection of plant varieties. The patenting of life form is related to **bio-piracy**, i.e., the stealing of resources and traditional knowledge from developing countries. A US patent on the use of turmeric for healing wounds is an example of bio-piracy. The issue of IPR protection of the genetically engineered crops is also very important. The International Union for Protection of New Varieties of Plants (UPOV) held its first convention in 1961, which has been revised several times. In 1991 revision, the breeder, who registers rights over varieties, can claim full commercial control over the seed or propagating material of their protected varieties. To control the ownership over the diversity, using genetic engineering, terminator seeds have been developed. **Terminator technology** generates infertile seeds; it forces the farmers to purchase seeds for every growing season. Hence this technology offers an inbuilt protection without the need of patenting. This issue is a matter of concern for developing countries; monopolisation of life and biological resources would adversely affect the development, food security, livelihood of farmers and the environment. Such patents are also being opposed by the people on ethical and moral grounds.

Protection and Restoration Techniques

Biodiversity banking: It is the process by which biodiversity loss can be reduced by placing monetary value on ecosystems services.

Gene banks: Gene banks help to preserve genetic material of living organisms. Location-specific approaches are less useful for protecting migratory species. Therefore there is need to create wildlife reserves, national parks and biosphere reserves. (See Appendix V.)

Legal status: Environmental laws are complex. They involve treaties, conventions, statutes regulation and common laws that operate to regulate the interaction of humanity and the natural environment (see Appendix IV). There are two major areas for which laws are enforced. One, related to pollution control and remediation and second, resource conservation and management. Pollution has no boundaries, making international law an important aspect of environmental law.

Resource allocation: Focusing on limited areas of higher potential biodiversity promises greater immediate return and areas that retain most of the original diversity, which does not require restoration. Biosphere reserves, national parks and biodiversity hotspots are the examples of setting up of resource allocation. (See Appendix V.)

Biodiversity Hotspots The bio-geographical region of the earth, which are extremely diverse with a high proportion of endemic species are the richest and most threatened reservoirs of plant and animal life on earth. Species are under severe threat due to habitat loss or climate change. The most remarkable places on earth are also the most threatened. The hotspots area of the remaining habitat covers only 2.3 per cent of the earth's land surface. Each hotspot faces extreme threats and has already lost at least 70 per cent of its original natural vegetation. Over 50 per cent of the world's plant species and 42 per cent of all terrestrial vertebrate species are endemic to the 34 biodiversity hotspots. About 25 sites worldwide are recognised as biodiversity hot spots. The 34 main hot spots are:

North and Central America
  California Floristic Province
  Caribbean Islands
  Madrean Pine-Oak Woodlands
  Mesoamerica
South America
  Atlantic Forest
  Cerrado
  Chilean Winter Rainfall—Valdivian Forests
  Tumbes-Choco-Magdalena
  Tropical Andes
Europe and Central Asia
  Caucasus
  Irano-Anatolian
  Mediterranean Basin
  Mountain of Central Asia
Africa
  Cape Floristic Region
  Coastal Forests of Eastern Africa
  Eastern Afromontane
  Guinean Forests of West Africa
  Horn of Africa
  Madagascar and Indian Ocean Islands
  Maputaland-Pondoland-Albany
  Succulent Karoo
Asia Pacific
  East Melanesian Islands
  Himalaya
  Indo-Burma
  Japan
  Mountains of Southwest China
  New Caledonia
  New Zealand
  Philippines
  Polynesia-Micronesia
  Southwest Australia
  Sundaland
  Wallacea
  Western Ghats and Sri Lanka

The hotspots provide us with the real measure of the conservation challenge. Unless we succeed in conserving this small fraction of the planet's land area, we will lose more than half of our natural heritage.

Biosphere Reserves (BR) The Man and Biosphere (MAB) program initiated in 1972 is a broad based ecological program aimed at improvement of the relationship between man and the environment. The approach emphasises on research and training and seeks scientific information to find solution to problems in management and conservation. The concept of biosphere reserves were adopted under the Convention on Biological Diversity (CBD) process on 29th December 1993. The CBD has two principal objectives, namely, "*Conservation and Sustainable use of Biological Diversity"* and "*Fair and Equitable sharing of benefits arising from its utilisation"*. The biosphere reserves are special sites for both people and the nature. The reserves contain genetic element evolved over millions of years that hold the key to future adaptations and survival. These sites have global importance, having tremendous potential for future economic development. The biosphere reserves have been categorised into three main areas.

- Core Area(s): These sites are dedicated to conservation. The core zone is kept absolutely undisturbed. It secures legal protection, management and research activities that do not affect natural processes. It is kept free from all human pressures.
- Buffer Area(s): It adjoins or surrounds the core zones and the activities here are managed in ways that protects the core zone. The activities include restoration and demonstration of sites for enhancing value addition to the resources. Activities such as recreation, tourism, fishing and grazing are limited.
- Transition Area(s): It is the outermost part of a biosphere reserve. This includes settlement, crop lands, managed forests and area for intensive recreation and other economic uses characteristic of the region.

In buffer and transition zones, manipulative macro-management practices are used. Experimental research areas are used for understanding the ecosystem. The understanding of ecosystem helps to restore the ecology in a way that it returns to sustainable productivity.

Characteristic of Biosphere Reserve (BR)

The main features are:

- Each reserve is a protected area of land and/ or coastal environments. People living in these areas are an integral component of the system. They constitute a worldwide network.
- Each BR includes the following category(s)
  (a) BRs must represent any of the natural biomes.
  (b) These areas may contain unique features of landscapes, ecosystems and genetic variations.
  (c) BRs have degraded ecosystems capable of being restored to natural conditions.
  (d) BRs have natural core area in combination with areas in which studies can be done.

Functions of Biosphere Reserves

- To promote economic, cultural, social and ecological development at the local level
- To develop the strategies for improvement and management of natural resources
- To ensure conservation of landscape, ecosystems, species and genetic variations
- To encourage the traditional ways of resources usage
- To understand the functioning of ecosystems
- To monitor the natural and human-caused changes
- To provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development
- Development of community services in the management of natural resources

When the word biosphere is followed by a number, it refers to a specific system or number. Thus:

- Biosphere 1 is the planet Earth.
- Biosphere 2 is a laboratory in Arizona which contains 3.15 acres of closed ecosystem.
- BIO-3 is a closed ecosystem at the institute of Biophysics in Krasnoyarsk, Siberia.
- Biosphere J (CEEF, Closed Ecology Experiment Facilities) is an experiment in Japan.

Biosphere Reserves: Indian Scenario

Indian geographical location is marked by mountain, coastal line, arid and semi-arid coupled with varied precipitations to constitute a rich landscape diversity.

India consists of

Two 'realms': The Himalayan region represented by Palearctic Realm and the rest of the sub-continent represented by Malayan realm

Five biomes: Tropical Humid Forest, Tropical Dry or Deciduous Forests, Warm deserts and semi-desert, Coniferous forest, Alpine Meadows

Ten bio-geographic zones: Trans Himalayan, Himalayan, Indian Desert, Semi-arid, Western Ghats, Deccan Penninsula, Gangetic Plain, North-East India, Islands, Coasts

Twenty five bio-geographical provinces: This diversity makes India as one of the mega-diversity zone. One biosphere in each of the bio-geographic province is the goal. India has created a network of protected areas in the form of 96 national parks, 510 wildlife sanctuaries and 28 tiger reserves and 25 elephant reserves. There 550 tribal communities of 227 ethnic groups spread over 5,000 forest villages. (Appendix V)

National Parks

In 1872, the world's first national park, Yellowstone National Park, at Montana and Wyoming was established. The national park system was originally composed of such large, scenic areas in the West as Yellowstone, Grand Canyon and Yosemite Valley. Today the national park system has more Cultural and historical sites (battlefields and historically important buildings and towns) than the place of scenic wilderness. In 1969 the IUCN (International Union for the Conservation of Nature and Natural resources) declared a park to be relatively large area with specific characteristics.

- A national park has one or more ecosystems. It is not exploited and occupied by humans. The plant and animal species, geomorphological sites and habitats are of special scientific, educative and recreative interest or a natural landscape of great beauty.
- The highest competent authority of the country has taken steps to prevent or eliminate exploitation or occupation.
- Visitors are allowed to enter, under special conditions, for inspirational, educative, cultural and recreative purposes.

In 1971 clear and well-defined specification for national park was further expanded. These are:

- A minimum of 1,000 hectares zone are considered as national park
- National park to have statutory legal protection
- A budget and staff sufficient to provide effective protection
- Prohibition of exploitation of natural resources (including the development of dams). Activities such as sports and fishing are allowed under the supervision of the management.

Conventions on Biodiversity

Although not formally a part of the UNCED (The United Nations Conference on Environment and Development) preparatory process, the Rio summit provided political impetus for completing the negotiations on the Convention on Biological Diversity (CBD). This was not the part of the formal UNCED process, but was an important parallel outcome. The aim of CBD is to promote the conservation and sustainable use of biodiversity through commitment, promoting scientific and technological cooperation, establishing protected areas, eradicating alien species, respecting and maintaining traditional knowledge and practices and providing financial resources. In January 2000, the *Cartagena Biosafety Protocol* was adopted to address potential risks associated with cross border trade and accident release of living modified organisms. This protocol was ratified at the Johannesberg Summit 2002.

Biodiversity and India

India is home to several well known large mammals including the Asian elephant, Bengal tiger, Asiatic lion, leopard and Indian rhinoceros. There are a wide range of ecozones—desert, high mountains, highlands, tropical and temperate forests, swamplands, plain, grasslands, area surrounding rivers as well as archipelago. There are three biodiversity hotspots: **the Western Ghats, the Eastern Himalayas** and **the hilly ranges at India-Myanmar border.** These hotspots have numerous endemic species. Since India is one of the eighteen mega-diverse countries, it is home to 7.6% of all mammalian, 12.6% of all avian, 6.2% of all reptilian, 4.4% of all amphibian, 11.7% of all fish and 6.0% of all flowering plant species in the world. The protected areas in India sum upto 92 national parks, 355 wildlife sanctuaries, 28 tiger reserves, 15 biosphere reserves, 4 coral reefs, 34 mangroove forests, 19 zoos. Many national and international agencies are working for conservation of biodiversity mainly *Project Tiger* and *Project Elephant*. India joined International Convention on Biological Diversity in 1994. The objectives of the convention are: conservation of biological diversity, sustainable use of its component and, fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. A national policy and action strategy on biodiversity to consolidate the ongoing efforts of conservation and sustainable use of biological diversity and to establish a policy and program regime for the purpose, was released by the government on May 2000. To achieve these goals Biodiversity Bill 2000 was passed in Parliament in December 2002. This bill seeks to check bio-piracy, protect biological biodiversity and local growers through a three-tier structure of central and state boards and local committees. These will regulate access to plant and animal genetic resources and share the benefits. The proposed National Biodiversity Authority (NBA) will deal with all cases of access by foreigners. Its approval will be required, before obtaining any intellectual property right on an invention, based on a biological resource from India or on its traditional knowledge. It will oppose such rights given in other countries. The NBA will enjoy the power of a civil court. In addition, the Centre may issue directives to any state, if it feels that a naturally rich area is threatened by overuse, abuse or neglect.

The Upcoming Events

The world is preparing to celebrate yet another milestone in 2012 through the United Nation Conference on Sustainable Development (UNCSD). The 11th conference of parties meeting, Convention on Biological Diversity (CBD-COP 11), will be held in October, 2012. It is hailed as the most progressive multilateral environmental agreement, offering a unique opportunity to operate on the principles of sustainable development.

Extinction is normal but the gravest part of both evolution and biodiversity crisis; it is irreversible; species arise and die. However the rate of extinction is alarmingly high, mainly due to human activity. Humans cause large environmental disruptions that result in loss of biodiversity. Human impacts have elevated the rate of extinction by at least a thousand times the natural rate of extinction. Mass extinctions of this magnitude have occurred five times in the history of our planet; the last brought the end of the dinosaur age. Some of these disruptions are the clear-cutting of forests and the deposition of contaminated sediments in lakes and oceans. Disruption, such as these lead to the fragmentation, degradation and loss of habitats.

Scientists predict that, as a result of human activities, average temperature will increase by 2°C–5°C in the near future. If the climate warms by only 2°C–5°C, some species will need to shift their ranges by as much as 500 to 800 kilometers within a single century. Some habitats, such as alpine tundra, could be eliminated as forests expand upto the mountain slopes.

Organisms, that are able to disperse easily such as most birds, may be able to shift their ranges as rapidly as the climate changes; provided that appropriate habitats exist in the new areas. About 8,000 years ago, when in North America glaciers retreated, the ranges of some of the coniferous trees expanded northward. On the other hand, some earthworm species spread only very slowly into the areas that had been covered by ice. If the earth's surface warms up, new climates will develop and some existing climates will disappear. The change of temperature will impact more at low elevations in the tropics. Adaptation to those climates may prove to be difficult for many tropical organisms. Although there has been little change in tropical region, the night temperature is slowly becoming warmer. During the warmer night, trees use more of their energy reserves which resulted in the reduction, of about 20 per cent, in the average growth rates of a few tree species. In 1998, the highest sea surface temperature caused corals to lose their endosymbiotic dinoflagellates and increased the mortality world-wide.

To preserve biodiversity, there is an urgent need to protect areas, restore habitat and develop programs to increase population of endangered species.

A.1.6 CLIMATE CHANGE

Anthropogenic (human-caused) climate change is an established phenomenon. The biggest culprit in climate change is an increase in atmospheric carbon dioxide, which is generated primarily through burning of fossil fuels. **Climate** is the prevailing weather condition in an area. The four main abiotic factors*:* *temperature, water*, *sunlight* and *wind* are the major components of climate. Climatic factor, especially temperature and water, have a major influence on the distribution of organisms. Climate patterns can be described on two scales: *Macroclimate* patterns are on global, regional or local levels and *Micro-*

climate patterns are very fine patterns such as the conditions experienced by a community of organisms under a fallen log. Forest trees moderate the micro-climate beneath them. Deforestation cleared area therefore experiences greater temperature extremes than the forest interior. Climate determines the makeup of biomes which are the major types of ecosystems. Global climate patterns are determined by sunlight and earth's movement in space. The sun's warming effect on the atmosphere, land and water establishes the temperature variations, cycles of air movement and evaporation of water that are responsible for latitudinal variations in climate.

Ocean currents influence climate along the coast by heating and cooling overlying air masses, which may pass over land. Coastal regions are generally more moist than inland areas of same latitude. In general, oceans and large lakes moderate the climate of nearby terrestrial environments. Ocean currents also influence climate in coastal areas. Mountains have significant effect on the amount of sunlight reaching an area, as well as on local temperature and rainfall. These environmental differences affect species distribution. At any given latitude, air temperature declines 6°C with every 1,000 meter increase in elevation. As moist warm air approaches a mountain, it rises and cools down, releasing moisture on the windward side of the peak. Deserts commonly occur on the leeward side of the mountain ranges. The changing angle of the sun over the course of a year affects the local environments. Belts of wet and dry air on either side of the equator shift with the changing angle of the sun. Lakes are also sensitive to seasonal temperature changes. During the summer and winter, many temperate lakes are thermally stratified or layered vertically according to temperature. These lakes undergo a semi-annual mixing or turnover of their waters in spring and fall. Turn-over brings oxygenated water to the bottom and nutrient-rich water to the surface.

Long-term climate changes profoundly affect the biosphere. One way to predict possible effect of current climate changes is to consider the climatic changes that have occurred in temperate regions since the end of the last ice age. There are latitudinal patterns of climate over the earth's surface; there are also latitudinal patterns of biome distribution. A **climograph** denotes the annual mean temperatures and precipitation of a region. Each biome has a characteristic climograph. Biomes are dynamic; and natural disturbance, rather than stability, tends to be the rule.

Terrestrial biome: Vertical stratification is an important feature of terrestrial biomes. The canopy of the tropical rain forest is the top layer, covering the low-tree stratum, shrub under-storey, ground layer, litter layer, and a root layer. Stratification of vegetation provides many different habitats for animals. Hurricanes create openings for new species in tropical and temperate forests. In northern coniferous forest, snowfall may break branches and small trees producing gaps that allow deciduous species to grow. In many biomes, the dominant plants depend on periodic disturbance e.g., natural wildfires are an integral component of savannas grasslands, chaparral and many coniferous forests. Human activities have radically altered the natural patterns of periodic physical disturbances. Fires are controlled for the sake of agriculture land. Humans have altered much of the earth's surface, replacing original biomes with urban or agricultural ones. Year 2010, witnessed many weather events due to change in climate. These are as follows:

- 2010 as warmest year on the record
- Heat waves in parts of Asia, Russia and Europe
- Pakistan flood
- El Nino to La Nina transition
- Brazilian drought
- Northeast Pacific hurricane
- Minimum sea ice extent
- China drought

The warming of the climate may lead to the creation of more extreme weather conditions:

(i) Hurricanes and drought frequencies may increase

(ii) Increase in duration of dry heat or heavy rains

(iii) The Arctic ice begins to melt
(iv) The Himalayan glaciers could retreat causing water shortage.

The Causes of Global Climate Change

Carbon dioxide (CO_2) and certain other trace gases including methane (CH_4), nitrous oxide (N_2O), chloroflurocarbons (CFCs) and Ozone (O_3) are accumulating in the atmosphere as a result of human activities. All of these are ***greenhouse gases*** which absorb radiated heat from the sun, thereby increasing the temperature of the atmosphere. Additionaly, though minor, greenhouse gases include carbon tetrachloride, methyl chloroform, chlorodifluromethane, sulfur hexafluoride, trifluoromethyl sulfur pentafluoride, fluoroform and perfluoroethane. The concentration of atmospheric carbon dioxide has grown from about 288 parts per million (ppm) approximately 200 years ago (before the Industrial Revolution) to 382 ppm in 2006. Because CO_2 and other gases slow the loss of heat generated by the incoming solar radiation, the natural trapping of heat in the atmosphere is often referred to as the **greenhouse effect**. The greenhouse gases accumulating in the atmosphere as a result of human activities are thus causing an *enhanced greenhouse effect*. There are different indications in the atmosphere which indicates climate change, some of these indicators are:

- More fossil fuel carbon in coral
- Nights warming faster than day
- 30 billion tones of CO_2 produced per year
- Less oxygen in the air
- Troposphere rising
- Thermosphere shrinking
- Less heat escaping to space
- Stratosphere cooling
- More fossil fuel carbon in the air
- Heat returning to earth

One of the complications that makes the rate and extent of global climate change difficult to predict is that other air pollutant, known as atmospheric aerosols, tend to cool the atmosphere, called the ***aerosol effect***. Aerosols, which come from both natural and human sources, are tiny particles, so small that they remain suspended in the troposphere for days, weeks, or months. Because sulfate particles are efficient at scattering radiation, a sulfate-laden haze tends to cool the planet by reflecting some of the incoming sunlight back into the space. By contrast, sooty aerosol generally absorbs radiation, and so they tend to warm up the planet. In the atmosphere, there are complex mixtures of aerosols of various types, making the actual aerosol effect on the climate relatively uncertain.

The Effects of Global Climate Change

Melting Ice and Rising Sea Levels The Inter-governmental Panel on Climate Change (IPCC) assessment reports predict, 18–59 cm, sea level rise by 2100. This rise can be caused in two ways;

- **Rise due to thermal expansion:** Water, like other substance expands as it warms. Thermal expansion contributes more than half of the rise in sea level. The current rate is about 3 mm per year.
- **Rise due to melting of glacier and thawing of ice at the south pole:** As the overall temperature of the earth has increased, a major thawing of glaciers and the polar ice caps has occurred. The area of ice-covered ocean in the Arctic has decreased significantly over the past several decades. Mountain glaciers around the world are also melting at accelerating rates.

Increasing Ocean Acidification As there is increase in CO_2 in the atmosphere; there is going to be more CO_2 in the oceans. The resulting change in the acid content of the ocean will disrupt the ability of plants and animals in the sea to make shells and skeleton of calcium carbonate. Marine creatures will have thinner shells or skeleton. This will decline the ocean biodiversity.

Changes in the precipitation patterns As the global climate change occurs, precipitation patterns will change, causing some areas to have frequent droughts. At the same time, heavier snow and rainstorms are projected to cause more frequent flooding in other areas.

Effects on Ecosystem The sustainability of ecosystem will be lost. Massive extinction of species will aggravate the environmental crisis. Sudden collapse of biological and ecological system may occur.

Effects on Organisms The biology of plants and animal species is fast changing as a result of climate warming, such as, early flowering for plant species; migrations of aquatic species. Changes are also evident in many populations, communities and ecosystems. Other human-induced factors, such as pollution and changes in land use, exacerbate threats posed by climate change. There are several studies conducted to date, which show impact of climate change on living organisms. The decline in zooplankton in the California Current has affected the entire food web; a similar decline in shrimp-like krill has contributed to a reduction in Adelie penguin population; temperature-related coral-bleaching occurs when temperature exceeds a threshold, affecting the coral symbiotes and making them and the corals more susceptible to disease-causing organisms that healthy corals are normally resistant to.

Effect on Human health The relationships between human health and climate work at the systemic level, and both are complex and inseparable. Some forms of impact are evident as, for example, the 2003 heat wave in France has resulted in around 15,000 deaths. The ranges of mosquitoes and other disease carriers are likely to expand into the newly warm areas and spread malaria, dengue fever, schistosomiasis, leishmaniasis and yellow fever.

Effect on Agriculture The rise in sea level may cause water to inundate river deltas, which are some of the world's best agricultural land. Certain agricultural pests and disease-causing organisms will proliferate and decrease the yields. The frequency of droughts will increase and soil moisture will decrease. There will be change in night-time temperatures, which has positive effects on some plants, but others like tomatoes will be difficult to grow. On a regional scale, agricultural productivity will increase in some areas and decline in others.

Increase in hunger all over the world The world is going to face food shortage. Increasing drought and desertification will spread.

International Implications of Global Climate change It will be difficult for all countries to develop a consensus on dealing with a climate change, partly because global climate change will clearly have greater impacts on some nations than on others. Tensions have increased among nations, especially between the highly developed and developing countries, over their differing self-interests. Highly developed nations have huge amounts of infrastructure at risk; the developing countries have less technical expertise and fewer economic resources, they are going to be least able to respond to the challenges of global climate change.

Ozone Depletion and Acid Deposition Lakes may be more susceptible to damage from UV radiation. The combined effects of acid deposition and climate warming may increase the extent to which the UV radiation penetrates the lake water. The increased UV penetration will disrupt photosynthesis in algae and aquatic plants and skin lesions in fishes. Acid deposition also affects the amount of dissolved organic compounds in the lake. The removal of organic acids from the water will allow more UV radiations to penetrate.

Dealing with Global Climate Change

Mitigation of Global Climate Change The development and use of alternatives to fossil fuels have the potential to eventually halt the warming caused by CO_2 emission. Alternatives to petroleum and natural gas are likely to become necessary over the coming decades. The energy use and greenhouse gas emissions can be significantly reduced, with little cost to society, by adopting the best technologies and implementing certain policies to encourage their use. For example, use of solar energy wherever possible and increasing the efficiency of automobiles and appliances would reduce the use of fossil fuels and the output of CO_2 emission; California took the lead in 2007, when the U.S. Supreme Court decided that the Environmental Protection Agency is required, under the Clean Air Act, to regulate CO_2 and other greenhouse gas emissions. One way to mitigate global climate change involves removing atmospheric carbon dioxide from the air by planting and maintaining forests.

Adaptation to Global Climate Change As the global climate change is inevitable, we must adapt. For example, the people living in coastal area could move to inland; we also must adapt to shifting agricultural zones. Evaluating the problems and finding and implementing solutions is the only remedy.

International Efforts to Reduce Greenhouse Gas Emissions At least 174 nations have now signed the U.N. Framework Convention on Climate Change (UNFCCC) developed at the 1992 Earth Summit. The international community recognises that the Kyoto Protocol is the only first step in addressing climate change.

Social Justice and Equity Developed countries are contributing more towards carbon emission. The largest share of global emissions of greenhouse gases has originated in developed countries. Per capita emissions in developing countries are still relatively low. It is not fair to expect the third world to make emissions reduction in the same ways. The social justice and equity dimensions are not considered in climate negotiations. The efforts to deal with the environmental issues should be considered globally. There are many issues that have not been covered at all.

GLOSSARY

Acclimation: The process by which numerous physical and physiological processes prepare the plant to survive in the adverse conditions.

Acid mine drainage: The outflow of acidic water from metal or coal mines.

Acid precipitation: Precipitation that is acidic as a result of both sulphur and nitrogen oxides forming acids when they react with water in the atmosphere; partially due to the combustion of coal; includes acid rain, acid snow and acid fog.

Adaptive radiation: The phenomenon by which a population of a species changes as it is dispersed in a different habitat within a region.

Aersol: Tiny particles of natural and human-produced air pollution that is so small they remain suspended in the atmosphere for days or even months.

Aersol effect: Atmospheric cooling that occurs where and when aerosol pollution is the greatest.

Agroforestry: The use of agricultural and forestry techniques to improve degraded soil and offer economic benefits.

Albedo: The proportional reflectance of sunlight from earth's surface; glaciers and ice sheets have high albedos, whereas the ocean and forests have low albedos.

Algal bloom: The rapid and excessive growth of algae; generally caused by high nutrient levels combined with other favourable conditions. It can deoxygenate the water leading to the loss of wildlife.

Alien species: A species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities; also known as introduced species.

Altruism: Behavior that harms the individual who perform it but benefits other individuals; parenting behaviors are altruistic behavior.

Big-bang: An explosion from a single point of super-condensed matter about 15 billion years ago that was the start of our universe.

Bioaccumulation: The accumulation of a substance, such as a toxic chemical, in the tissues of a living organism.

Biochemical oxygen demand (BOD): The amount of oxygen needed by microorganisms to decompose the organic material in a given volume of water; also called biological oxygen demand.

Biocoenosis: All the interacting organisms living together in a specific habitat; also called biocoenose or biocenose.

Biodiversity hotspots: The small area of land that contain an exceptional number of endemic species and are at high risk from human activities.

Biogas: A clean fuel whose combustion produces fewer pollutants than coal or biomass; it is produced from the anaerobic digestion of organic material.

Biological magnification: It is also called bioaccumulation; is the process whereby certain substances such as pesticides or heavy metals move up the food chain.

Biome: A complex of terrestrial community of very wide extent, characterised by its climate and soil; the largest ecological unit.

Biota: The total flora and fauna of a region.

Blue revolution: It refers to the management of water resources that can steer humanity to achieve drinking water and crop irrigation security. It is water equivalent of the green revolution.

Buffer zone: The region near the border of a protected area; a transition zone between areas managed for different objectives.

Carbon credit: A way of reducing the impact of greenhouse gas emissions; it allows an agent to benefit financially from an emission reduction. It represents one tonne of carbon dioxide either removed from the atmosphere or saved from being emitted. It is also known as emission permit.

Carbon footprint: A measure of the carbon emissions that are emitted over the full life cycle of a population, system, product or service and usually expressed as grams of carbon dioxide equivalent (CO_2-e).

Carrying capacity: The number of individuals within a population that can be supported within a particular environment for an indefinite time.

Chaparral: Chaparral vegetation is characterised by small-leaved evergreen shrubs and small trees. The climate of the region is mild, moist winters and hot dry summers.

Chlorofluorocarbon: Compounds of chlorine, fluorine and carbon that have been contributing to ozone depletion.

Climate Feedback: A process that acts to amplify or reduce direct warming or cooling effects.

Climax community: A community in which the mix of plants and animals become stable; the last stage of succession.

Cline: A gradual change in the traits of a species over a geographical gradient.

Community: A group of mutually adjusted populations of plants and animals inhabiting a natural area.

Comparative risk assessment: A methodology which uses science, policy, economic analysis and stakeholder participation to identify and address areas of greatest environmental risk; a method for assessing environmental management priorities.

Composting: The biological decomposition of organic materials in the presence of oxygen that yields carbon dioxide, heat, and stabilised organic residues that may be used as a soil additive.

Conservation biology: A discipline of ecology which deals with identifying all species and to design long-term management programs based on ecological and evolutionary principles.

Decomposers: Organisms which digest or break down living material which has died.

Deme: Any local population of individuals belonging to the same species that can inter-breed with one another.

Demography: The statistical analysis of human population.

Detritivore: An organism that obtains its energy from dead bodies and/or waste product of other animals.

Detritus: The waste material of an ecosystem.

Ecological footprint: The amount of land and ocean needed to supply an individual with food, energy, water, housing, transportation and waste disposal.

Ecological niche: The functioning of a species in relation to other species and its physical environment.

Ecological succession: The sequential replacement of one assemblage of populations by another in a habitat following some disturbance.

Ecotone: The transitional zone where two ecosystem or biomes inter-grade.

Ecotourism: A type of tourism in which tourist pay to observe wildlife in natural settings.

Ecotype: A locally adapted variant of an organism, differing genetically from other ecotype.

Endangered species: The species that face a very high risk of extinction in near future.

Endemic species: The native or local species that are not found anywhere else in the world.

Environmental carrying capacity (K): The number of individuals in a population that the resources of a habitat can support.

Environmental contamination: The presence of toxic substance in a habitat.

Environmental ethics: It is the field of applied ethics that consider the moral basis of environmental responsibility; it also considers how humans should relate to the natural environment.

Ethology: An approach to study the animal behavior in the natural environment. Examine the causes of the evolution of behavior.

Eutrophication: The addition of nutrient materials to a body of water, which stimulates plant growth; resulting in changes in ecological processes and species composition there in; the decomposition process, takes oxygen from the water, leading to death of other species.

Evolutionary psychology: The science that explains the behavior of our ancestors as a direct result of adaptive evolution.

Flora: All of the plants found in a given area.

Food chain: A portion of a food web, most commonly a simple sequence of prey species and predator that consume them.

Food web: The complete set of food links between species in a community; a diagram indicating which ones are the eaters and which one are eaten.

Forb: Any broadleaf herbaceous plant growing in grasslands.

Founder effect: The extreme genetic drift because of isolation of a small population from a large population.

Fundamental niche: The role an organism might play in an ecosystem in the absence of competitor.

Gene-for-gene resistance: A mechanism for resistance to pathogens, in which resistance is triggered by the specific interaction of the products of the pathogens.

Green architecture: The practice of designing and building homes with environmental considerations such as energy efficiency, recycling and conservation of natural resources in mind.

Greenhouse effect: The heating of earth's atmosphere by gases such as water vapor, carbon dioxide and methane; such greenhouse gases are transparent to sunlight and opaque to heat; thus sunlight-engendered heat builds up at earth's surface and cannot be dissipated into the atmosphere.

Greenhouse gas: A gas that absorbs infrared radiation; carbon dioxide, methane, nitrous oxide, chlorofluorocarbons and troposphere ozone are all greenhouse gases.

Habitat loss: The shrinkage and fragmentation of the habitat (the place where the organism grows) in which the species lives.

Habituation: The ability of an organism to get used to certain types of stimuli.

Halophyte: A plant that grows in a saline environment.

Hominins: All living and extinct human species, the only living hominines is *Homo sapiens*.

Indicator species: Any biological species that defines a trait or characteristic of the environment.

Keystone species: Species that have dominant influence on the composition of a community.

Landscape ecology: A sub discipline in ecology that focuses on connections among ecosystems in a particular area.

Macro consumers: Large organisms, mainly animals, which eat other organisms or organic matter; also called phagotrophs.

Micro consumers: Micro-organisms, such as bacteria and fungi, which break down the complex compounds of dead cells and absorb some of the decomposed products; also known as saprotrophs or osmotrophs.

Municipal solid waste: The waste which includes paper, yard waste, food waste, plastics, metals, textiles, glass wood etc; but does not include agricultural and industrial wastes.

Nitrogenous waste: Nitrogen containing molecules that are produced as waste by the breakdown of proteins and nucleic acids.

Omnivore: A living organism that consumes both plant and animal food.

Plankton: Free-floating small organism inhabiting the surface water of lakes and oceans. Photosynthetic members of the plankton are referred as phytoplankton.

Protobiont: Aggregates of abiotically produced molecules surrounded by membrane; it cannot reproduce but do maintain internal chemical environment that differ from their surroundings.

Reconciliation ecology: The practice of making exploited lands more biodiversity-friendly.

Red tide: A red, orange or brown coloration of water caused by a bloom or population explosion of algae; red tides cause serious environmental harm and threaten the health of humans and animals.

Restoration ecology: The science and practice of restoring damaged or degraded ecosystems.

Secondary succession: Ecological succession after a disturbance that did not eliminate all the organisms originally living in the site.

Seed-tree cutting: A forest management technique in which almost all trees are harvested from an area in a single cutting, but a few desirable trees are left behind to provide seeds for the regeneration of the forest.

Shelterwood cutting: A forest management technique in which all mature trees in an area are harvested in a series of partial cutting over time.

Succession: It is a process of change during which a sequence of communities replaces one another in an orderly and predictable way.

Trophic cascade: The progression over successively lower trophic levels of the indirect effects of predator.

Understory: The small plants growing under the canopy of dominant plants.

Vulnerable species: A species which is likely to become endangered unless the circumstances threatening its survival and reproduction improve.

MULTIPLE CHOICE QUESTIONS

1. Noted environmentalist Vandana Shiva played a key role in the Indian legal challenge to US patent on which plant/s?
    1. Neem 2. Haldi
    3. Rice 4. Saffron

   Select the correct answer using the codes given below.
   (a) 1 only (b) 2 only
   (c) 3 and 2 only (d) 1, 2 and 4 only

2. Paddy fields are a chief source of which greenhouse gas/es?
    1. Methane 2. Carbon dioxide
    3. Nitrous oxide

   Select the correct answer using the codes given below:
   (a) 1 only (b) 2 only
   (c) 1 and 3 only (d) 1, 2 and 3

*3. Which one of the following organisation won the CSIR Award for Science and Technology (S&T) Innovations for Rural Development, 2006?
   (a) IARI (b) NDDB
   (c) NDRI (d) CLRI

4. Consider the following statements regarding the use of disposable plastic plates.
    1. Toxic chemicals are present in its production.
    2. They are non- biodegradable.
    3. They are light in weight.
    4. They are biodegradable.

   Which of the above given statements is/are correct?
   (a) 1 and 4 only (b) 2 only
   (c) 2 and 3 only (d) 3 and 4 only

5. Which of the following groups contain only non-biodegradable materials?
    1. Wood, paper and leather
    2. Plastic, Bakelite, DDT
    3. Plastic, thermo coal, wood
    4. Thermo coal, plates made from dried leaves, detergents

   Select the correct answer using the codes given below.
   (a) None of the above
   (b) 2 only
   (c) 2 and 3 only
   (d) 3 and 4 only

*6. Which is one of the following is also known as "Top Slip"?
   (a) Simplipal National Park
   (b) Periyar Wildlife Sanctuary
   (c) Manjira Wildlife Sanctuary
   (d) Indira Gandhi Wildlife Sanctuary

*7. Consider the following statements:
    1. In India, Red Panda is naturally found in the Western Himalayas only.
    2. In India, Slow Loris lives in the dense forests of the North East.

   Which of the statements given above is/are correct?
   (a) 1 only (b) 2 only
   (c) Both 1 and 2 (d) Neither 1nor 2

8. Epiphytes are the plants which grow on the bark of trees' branches to obtain adequate light and water and not the nutrient from the plant. This type of interaction is known as
   (a) Mutualism (b) Commensalism
   (c) Parasitism (d) Amenalism

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* Questions that have appeared in previous civil services examinations.

9. Consider the following statements:
   What is the difference between a national forest and a national park?
   1. A national forest is a working forest; it provides a nation with raw materials, wildlife habitat; while a national park is not managed for resource production.
   2. A national forest gives protection to fauna only; while a national park gives protection to both flora and fauna.
   3. A national forest is a working forest; a national park is in the city and gives protection to flora only.
   4. A national forest protects only the trees and animals; a national park is in the city and has no defined role in protection of flora and fauna.

   Which of the above given statements is/are correct?
   (a) 1 only (b) 1 and 4 only
   (c) 2 only (d) 3 only

*10. In the context of CO_2 emission and global warming, what is the name of a market driven device under UNFCC that allows developing countries to get funds/incentives from the developed countries to adopt better technologies that reduce greenhouse gas emission?
   (a) Carbon foot printing
   (b) Carbon credit rating
   (c) Clean development mechanism
   (d) Emission reduction norm

11. The study of the Environmental Sciences includes which of the following?
   1. Traditional science
   2. Societal values
   3. Political awareness

   Select the correct answer using the codes given below
   (a) 1 and 2 only
   (b) 1 and 3 only
   (c) None of the above
   (d) All of the above

12. Social and political decisions are made with respect to political jurisdictions; environment problems
   (a) respect political boundaries
   (b) often have little to do with regional economic decisions
   (c) often transcend these jurisdictions
   (d) none of the above

13. Environmental scientists use an ecosystem approach to understand environmental problems. Which of the following will be taken into account?
   1. The interrelationship between the organisms.
   2. Human activity
   3. Geography

   Select the correct answer using the codes given below:
   (a) 1 only (b) 2 only
   (c) 1 and 2 only (d) 1, 2 and 3

*14. The concept of carbon credit originated from which one of the following?
   (a) Earth Summit, Rio de Janerio
   (b) Kyoto Protocol
   (c) Montreal Protcol
   (d) G-8 Summit, Heiligendamm

15. How does the gap between rich and poor countries contribute to the current environmental crisis?
   1. Rapid industrialisation in developing countries poisons the cities.
   2. Developed countries consume a disproportionate share of the resources.
   3. Increased agricultural production in developing countries often destroys soil and forests.

   Which of the above given statements are true?
   (a) 1 and 2 only (b) 1, 2 and 3
   (c) 1 and 3 (d) 2 and 3

16. When tall trees shade out short and shade-intolerant species, the interaction is known as
   (a) Parasitism

(b) Predation
(c) Habitat destruction
(d) Competition

17. Consider the following pairs:
    1. Carnivore—Red-tailed Hawk
    2. Herbivore—Field mouse
    3. Decomposer—Termites
    4. Producer—Pitch Pine
    5. Detritivore—Earthworm
    6. Omnivore—Pigs

    Which of the above given pairs are matched correctly?
    (a) All of the above
    (b) None of the above
    (c) 1, 2, 3 and 4
    (d) 3, 4, 5 and 6

18. Green plants do not photosynthesise during night time, then how early morning walk is considered to be more beneficial?
    (a) Green algae and cyanobacteria in marine environment provide about 70% of the free oxygen. The terrestrial plants have no contribution on the free oxygen on the earth.
    (b) Early in the morning there is comparatively low level of air pollution.
    (c) Plants are very important in the cycling of carbon dioxide.
    (d) None of the above.

19. Which of the following would be the part of the carbon cycle?
    1. Animal respiration
    2. Plant respiration
    3. Production of sugars in plants
    4. Production of proteins in animals

    Select the correct answer using the codes given below.
    (a) 1, 2 and 3 (b) 1, 2 and 4
    (c) 2,3 and 4 (d) All of the above

20. Consider the following statements.
    Rachel Carson's book *Silent Spring* (1962) was about
    1. The potential ecological devastation of pesticide, such as DDT, in the ecosystem
    2. Rapid global warming resulting from fossil fuel burning and deforestation
    3. The potential for resource depletion leading to global poverty and starvation from increasing population control
    4. Socio-economic chaos resulting from a computer virus and over-concentration on technology and computers

    Which of the above given statements is/are correct?
    (a) 1 only (b) 2 only
    (c) 1 and 3 only (d) None of the above

21. What is the significance for targeting 'biodiversity hotspots' for conservation?
    1. These are the areas where more species are threatened.
    2. These areas are not inhabited by people, therefore conservation would not be effecting the economic development of the area.
    3. To protect all areas of threatened species would not allow new species to develop.
    4. It is not possible to protect species worldwide, thus it is decided to concentrate on areas which are rich in biodiversity.

    Select the correct answer using the codes given below.
    (a) 1 and 4 (b) 2 only
    (c) 1 and 3 only (d) 4 only

22. Ecology is to environmental science as
    (a) Engineering is to physics
    (b) Physics is to engineering
    (c) Environmental science is to physics
    (d) Physics is to environmental science

23. Which material from large explosive volcanic eruptions results in decrease in temperature?
    1. Carbon dioxide (CO_2)
    2. Sulfur dioxide (SO_2)
    3. Water vapour (H_2O)
    4. Radon (Rn)

Select the correct answer using the codes given below.

(a) 1 only (b) 2 only
(c) 1 and 2 only (d) 3 and 4 only

24. In a sealed container, take measured quantities of ozone, oxygen, chlorofluorocarbons and a source emitting ultraviolet radiations. What will happen after one month of exposure to ultraviolet radiation?

	Ozone	Oxygen	CFC
(a)	Decrease	Increase	Decrease
(b)	Increase	Increase	Increase
(c)	Increase	Decrease	Decrease
(d)	Decrease	Decrease	Increase

*25. In the context of the affairs of which of the following is the phrase "Special Safeguard Mechanisms" are mentioned in the news frequently?

(a) United Nations Environment Programme
(b) World Trade Organisation
(c) ASEAN-India Free Trade Agreement
(d) G-20 Summits

26. Why does a change of climate occur in the months following a major explosive volcanic eruption?

1. An increase in rainfall due to the loss of vegetation cover
2. An increase in average temperature due to the heat released by erupting volcanoes
3. A decrease in average temperature due to the increase in fine particle reflecting solar radiation
4. A decrease in average temperature due to increased carbon dioxide absorbing heat from the atmosphere

Which of the above given statements is/are correct?

(a) 1 and 3 only (b) 2 only
(c) 3 only (d) 1 and 4 only

27. It may take 10 million years to change from greenhouse to icehouse conditions on earth. Which one of the following can be the probable cause/s for this change?

1. Accumulation of carbon dioxide
2. Drifting of Antarctic plate
3. Formation of dust clouds due to meteorite impacts
4. Removal of carbon dioxide

Which of the above given statements is/are correct?

(a) 1 only (b) 2 and 4 only
(c) 1, 2 and 3 only (d) 4 only

28. When is Van Mahotsav's Day celebrated?

(a) 2nd October (b) 1st December
(c) 10th July (d) 1st July

29. Consider the following statements about "Terminator Technology".

1. Termination of crop pesticides
2. Transgenic varieties are going to terminate the existing varieties
3. High yielding hybrid seed for consumption; it cannot be used as seeds for next sowing
4. Termination of expression of a gene

Which of the above given statements is/are not correct?

(a) 1 only (b) 1 and 3 only
(c) 3 only (d) All of the above

*30. Consider the following statements.

1. Biodiversity hot spots are located only in tropical region.
2. India has four biodiversity hotspots i.e. Eastern Himalayas, Western Himalayas, Western Ghats and Andaman and Nicobar Islands.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

*31. Consider the following statements.

1. The boundaries of a National Park are defined by legislation.
2. A Biosphere Reserve is declared to conserve a few specific species of flora and fauna.
3. In a Wildlife Sanctuary, limited biotic interference is permitted.

Which of the above statement is/are correct?

(a) 1 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

*32. A pesticide which is chlorinated hydrocarbon is sprayed on a food crop. The food chain is: Foodcrop-Rat-Snake-Hawk. In this food chain, the highest concentration of the pesticide would accumulate in which one of the following?

(a) Food crop (b) Rat

(c) Snake (d) Hawk

*33. With reference to soil conservation, consider the following practices.

1. Crop rotation
2. Sand fences
3. Terracing
4. Wind breaks

Which of the above are considered appropriate methods for soil conservation in India?

(a) 1, 2 and 3 only (b) 2 and 4 only

(c) 1, 3 and 4 only (d) 1, 2, 3 and 4

*34. An objective of the National Food Security Mission is to increase the production of certain crops through area expansion and productivity enhancement in a sustainable manner in the identified district of the country. What are those crops?

(a) Rice and Wheat only

(b) Rice, Wheat and Pulses only

(c) Rice, Wheat, Pulses and oil seeds only

(d) Rice, Wheat, pulses, oil seeds and vegetables

*35. The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty drawn at

(a) United Nations Conference on the Human Environment, Stockholm, 1972

(b) UN Conference on Environment and Development, Rio de Janerio, 1992

(c) World Summit on Sustainable Development, Johannesburg, 2002

(d) UN Climate Change Conference, Cophenhagen, 2009

*36. Which bacterial strain, developed from natural isolates by genetic manipulation, can be used for treating oil spills?

(a) *Agrobacterium* (b) *Clostridium*

(c) *Nitrosomonas* (d) *Pseudomonas*

*37. India is party to the Ramsar Convention and has declared many areas as Ramsar Sites. Which of the following statements best describes as to how we should maintain these sites in the context of this convention?

(a) Keep all the sites completely inaccessible to man so that they will not be exploited

(b) Conserve all the sites through ecosystem approaches and permit tourism and recreation only

(c) Conserve all the sites through ecosystem approach for a period without any exploitation, with specific criteria and specific period for each site, and then allow sustainable use of them for future generations

(d) Conserve all the sites through ecosystem approach and allow their simultaneous sustainable use

*38. Due to their extensive rice cultivation, some regions may be contributing to global warming. To what possible reason/reasons is this attributable?

1. The anaerobic conditions associated with rice cultivation cause the emission of methane.
2. When nitrogen based fertilisers are used, nitrous oxide is emitted from the cultivated soil.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

*39. Sustainable development is described as the development that meets the needs of the present, without compromising the ability of future generations, to meet their own needs. In this perspective, inherently the concept of sustainable development is intertwined with which of the following concepts?

(a) Social justice and empowerment
(b) Inclusive growth
(c) Globalisation
(d) Carrying capacity

*40. Consider the following pairs:

	Protected area	**Well-known for**
1.	Bhitarkanika, Orissa	Salt water Crocodile
2.	Desert National Park,	Great Indian Bustard Rajasthan
3.	Eravikulam, Kerala	Hoolak Gibbon

Which of the pair given above is/are correctly matched?

(a) 1 only (b) 1 and 2 only
(c) 2 only (d) 1, 2 and 3

*41. In India, which type of forest among the following occupies the largest area?

(a) Montane wet temperate forest
(b) Sub-tropical dry evergreen forest
(c) Tropical moist deciduous forest
(d) Tropical wet evergreen forest

*42. Consider the following statements:

1. The Taxus tree is naturally found in the Himalayas.
2. The Taxus tree is listed in the Red Data Book.
3. A drug called "taxol" obtained from Taxus tree, is effective against Parkinson's disease.

Which of the above given statements is/are correct?

(a) 1 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

*43 What are the possible limitations of India in mitigating the global warming at present and in the immediate future?

1. Appropriate alternate technologies are not sufficiently available.
2. India cannot invest huge funds in research and development.
3. Many developed countries have already set up their polluting industries in India.

Which of the statements given above is/are correct?

(a) 1 and 2 only (b) 2 only
(c) 1 and 3 only (d) 1, 2 and 3

44. Consider the following pairs:

1. Boreal Forest–high productivity; rapid cycling of nutrients (poor reservoir)
2. Perma frost–swamp forest
3. Chaparral–a type of dry shrub land
4. Tropical rain forest–feature arctic tundra

Select the correctly matched pair/s using the codes given below.

(a) 1, 2 and 3 only (b) 1 and 2 only
(c) 3 only (d) None of the above

45. Biogeographic realms are

1. Land and water provinces
2. Six major land provinces
3. Divided into biomes

Select the correct answer using the codes given below.

(a) 1 and 2 only (b) 1 and 3 only
(c) 1, 2 and 3 only (d) 2 and 3 only

46. Dominant plants of which type are highly adapted to recurring episodes of lightning-sparked fires?

1. Dry shrub lands
2. Grasslands
3. Southern pine forests

Select the correct answer using the codes given below.

(a) 1 and 2 only (b) 3 only
(c) 1 and 3 only (d) 1, 2 and 3

47. Biome distribution corresponds roughly with regional variations in

1. Climate
2. Soils
3. Topography

Select the correct answer using the codes given below

(a) 1 only (b) 2 and 3 only

(c) 1 and 2 only (d) 1, 2 and 3

48. Consider the following pairs:

1. Marine snow–deep cool, often nutrient-rich ocean water moves upwards
2. Upwelling–partially enclosed mix of sea water and fresh water
3. Eutrophication–nutrient enrichment of body of water; reduced transparency, Phytoplankton blooms
4. Estuary–basis of mid-oceans food webs

Select the correct pair using the codes given below.

(a) 3 only (b) 4 only

(c) 1 and 2 only (d) None of the above

49. Pollutants disrupt ecosystems because

(a) Their component differ from those of natural substances.

(b) Only humans have uses for them.

(c) There is no mechanism to deal with them.

(d) Their only effect is on ecosystem, not humans.

50. Which of the following is/are responsible for regional air pollution?

1. Smog
2. Acid rain
3. Ozone layer thinning

Select the correct answer using the codes given below.

(a) 1 only (b) 2 only

(c) 1 and 3 only (d) All of the above

*51. Which one of the following is not a site for in-situ methods of conservation of flora?

(a) Biosphere Reserve

(b) Botanical Garden

(c) National Park

(d) Wildlife Sanctuary

*52. Three of the following criteria have contributed to the recognition of Western Ghats—Sri Lanka and Indo-Burma regions as hotspots of biodiversity.

1. Species richness
2. Vegetation destiny
3. Endemism
4. Ethno-botanical importance
5. Threat perception
6. Adaptation of flora and fauna to warm and humid conditions

Which three of the above are correct criteria in this context?

(a) 1, 2 and 6 (b) 2, 4 and 6

(c) 1, 3 and 5 (d) 3, 4 and 6

*53. The Himalayan Range is very rich in species diversity. Which one among the following is the most appropriate reason for this phenomenon?

(a) It has a high rainfall that supports luxuriant vegetative growth.

(b) It is a confluence of different biogeographical zones.

(c) Exotic and invasive species have not been introduced in this region.

(d) It has less human interference.

54. Consider the following pairs:

1. Desertification—converting the large tract of desert to natural grassland like State
2. deforestation—soil loss, watershed damage, altered rainfall patterns follow
3. Green revolution—attempt to improve crop production on existing land
4. Solar-hydrogen power—is not the best option
5. CFCs—invisible, odorless compounds that contribute to ozone thinning

Which of the above given statements are correct?

(a) 2, 3 and 5 only (b) 2 and 4 only

(c) All of the above (d) None of the above

55. The characteristic feature/s of the ecosystems is/are

1. Energy inputs and outputs
2. One trophic level
3. Nutrient cycling but not outputs

Select the correct answer using the codes given below.

(a) 1 only (b) 1 and 2 only
(c) 1, 2 and 3 (d) 3 only

56. Trophic levels are
    1. Structure feeding relationships
    2. Who eats whom in an ecosystems
    3. A hierarchy of energy transfer

    Select the correct answer using the codes given below.

    (a) 1 and 2 only (b) 1 and 3 only
    (c) 2 and 3 only (d) 1, 2 and 3

57. Consider the ecosystems terms with the suitable description.
    1. Producers—photoautotrophs
    2. Consumers—feed on partly decomposed matter
    3. Decomposers—decade organic remains, wastes
    4. Detritivores—herbivores, carnivores, omnivores

    Select the correct answer using the codes given below.

    (a) 1 and 2 only (b) 1 and 3 only
    (c) 1 only (d) 1, 2, 3 and 4

58. A habitat
    1. Has distinguished physical and chemical features.
    2. Is where individuals of a species normally live.
    3. Is occupied by various species.

    Select the correct answer using the codes given below.

    (a) 1 and 2 only (b) 1 and 3 only
    (c) 2 and 3 only (d) 1, 2 and 3

59. A two-way flow of benefits in mutualistic interactions between species is an outcome of
    (a) Close cooperativeness
    (b) Resource partitioning
    (c) Two-way exploitation
    (d) Competitive coexistence

60. Two species in the same habitat can coexist when they
    1. Differ in their use of resources.
    2. Share the same resource in different ways.
    3. Use the same resource at different times.

    Select the correct answer using the codes given below.

    (a) 1 and 3 only (b) 2 only
    (c) 3 only (d) 1, 2 and 3

*61. The 2004 Tsunami made people realise that mangroves can serve as a reliable safety hedge against coastal calamities. How do mangroves function as safety hedge?
    (a) The mangrove swamps separate the human settlements from the sea by a wide zone in which people neither live nor venture out.
    (b) The mangrove provides both food and medicines which people are in need of after any natural disaster.
    (c) The mangrove trees are tall with dense canopies and serve as an excellent shelter during a cyclone or tsunami.
    (c) The mangrove trees do not get uprooted by storms and tides because of their extensive roots.

*62. The "Red Data Book" published by the International Union for Conservation of Nature and Natural Resources (IUCN) contain lists of
    1. Endemic plant and animal species present in the biodiversity hotspots.
    2. Threatened plant and animal species.
    3. Protected sites for conservation of nature and natural resources in various countries.

    Select the correct answer using the codes given below.

    (a) 1 and 3 (b) 2 only
    (c) 2 and 3 (d) 3 only

*63. La Nina is suspected to have caused recent floods in Australia. How is La Nina different from El Nino?

1. La Nina is characterised by unusually cold ocean temperature in the equatorial Pacific Ocean.
2. El Nino has adverse effect on south-west monsoon of India, but La Nina has no effects on monsoon climate.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

*64. Consider the following statements.

1. Biodiversity is normally greater in the lower latitudes as compared to the higher altitudes.
2. Along the mountain gradients, biodiversity is normally greater in the lower altitude as compared to higher altitudes.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

*65. Microbial Fuel cells are considered a source of sustainable energy. Why?

1. They use living organisms as catalysts to generate electricity from certain substrates.
2. They use a variety of inorganic materials as substrates.
3. They can be installed in waste water treatment plants to cleanse water and produce electricity.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

*66. With what purpose is the Government of India promoting the concept of "Mega Food Parks"?

1. To provide good infrastructure facilities for the food processing industries
2. To increase the processing of perishable items and reduce wastage
3. To provide emerging and ecofriendly food processing technologies

Select the correct answer using the codes given below.

(a) 1 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

*67. Biodiversity forms the basis for human existence in the following ways:

1. Soil formation
2. Prevention of soil erosion
3. Recycling of waste
4. Pollination of crops

Select the correct answer using the codes given below.

(a) 1, 2 and 3 only (b) 2, 3 and 4 only
(c) 1 and 4 only (d) 1, 2, 3 and 4

*68. Which one of the following is located in the Bastar region?

(a) Bandhavgarh National Park
(b) Dandeli Sanctuary
(c) Rajaji National Park
(d) Indravati National Park

*69. Consider the following

1. Rice Fields 2. Coal mining
3. Domestic animals 4. Wet lands

Which of the above are sources of methane, a major greenhouse gas?

(a) 1 and 4 only (b) 2 and 3 only
(c) 1, 2 and 3 only (d) 1, 2, 3 and 4

70. In a food chain of cat, seed-eating birds, plants and dog, which one will have maximum pesticides?

(a) Cat (b) Plants
(c) Dog (d) Seed-eating birds

*71. Which one of the following Union Ministries implements the Cartagena protocol on biosafety?

(a) Ministry of Science and Technology
(b) Ministry of Health and Family Welfare
(c) Ministry of Environment and Forests
(d) Ministry of Chemicals and Fertilisers

72. The three Rs denote:
    - (a) Reduce, Regenerate, Recycle
    - (b) Recycle, Regenerate, Reuse
    - (c) Reduce, Recycle, Reuse
    - (d) Reduce, Regenerate, Reuse

73. A predator and prey population
    1. Always coexist at relatively stable levels.
    2. May undergo cyclic or irregular changes in density.
    3. Cannot coexist indefinitely in the same habitat.

    Select the correct answer using the codes given below:

    (a) 1 only (b) 2 only
    (c) 1 and 2 only (d) 1 and 3 only

74. Consider the following features of parasites. They
    1. Tend to kill their hosts.
    2. Feed on host tissues.
    3. Can kill novel host.

    Select the correct answer using the codes given below.

    (a) 1 only (b) 2 only
    (c) 1 and 3 only (d) 2 and 3 only

75. The biodiversity of a given region is an outcome of
    1. Climate and topography
    2. Possibilities for dispersal
    3. Evolutionary history

    Select the correct answer using the codes given below.

    (a) 1 only (b) 2 and 3 only
    (c) 1 and 3 only (d) 1, 2 and 3

*76. Consider the following protected areas:
    1. Bandipur
    2. Bhitarkanika
    3. Manas
    4. Sunderbans

    Which of the above are declared Tiger Reserves?

    (a) 1 and 2 only (b) 1, 3 and 4 only*
    (c) 2, 3 and 4 only (d) 1, 2, 3 and 4

*77. In which one among the following categories of protected areas in India is local people are not allowed to collect and use the biomass?
    - (a) Biosphere reserves
    - (b) National Parks*
    - (c) Wetlands declared under Ramsar Convention
    - (d) Wildlife Sanctuaries

*78. Consider the following kinds of organisms.
    1. Bat
    2. Bee
    3. Bird

    Which of the above is/are pollinating agent/s?

    (a) 1 and 2 only (b) 2 only
    (c) 1 and 3 only (d) 1, 2 and 3

*79. Which one of the following groups of animals belongs to the category of endangered species?
    - (a) Great Indian Bustard, Musk Deer, Red Panda and Asiatic Wild Ass
    - (b) Kashmir Stag, Cheetal, Blue Bull and Great Indian Bustard
    - (c) Snow Leopard, Swamp Deer, Rhesus Monkey and Saras (Crane)
    - (d) Lion-tailed, Macaque, Blue Bull, Hanuman Langur and Cheetal

*80. The Millennium Ecosystem Assessment describes the following major categories of ecosystem services—provisioning, supporting, regulating, preserving and cultural. Which one of the following is a supporting service?
    - (a) Production of food and water
    - (b) Control of climate and disease
    - (c) Nutrient cycling and crop pollination
    - (d) Maintenance of diversity

*81. What is the difference between the antelopes Oryx and Chiru?
    - (a) Oryx is adapted to live in hot and arid areas whereas Chiru is adapted to live in steppes and semi-desert areas of cold high mountains.

(b) Oryx is poached for its antlers whereas Chiru is poached for its musk.

(c) Oryx exists in western India only whereas Chiru exists in north-east India only.

(d) None of the statements (a), (b) and (c) given above is correct.

*82. Which of the following can be threats to the biodiversity of a geographical area?

1. Global warming
2. Fragmentation of habitat
3. Invasion of alien species
4. Promotion of vegetarianism

Select the correct answer using the codes given below.

(a) 1, 2 and 3 only (b) 2 and 3 only
(c) 1 and 4 only (d) 1, 2, 3 and 4

*83. Consider the following:

1. Black-necked crane
2. Cheetah
3. Flying squirrel
4. Snow leopard

Which of the above are naturally found in India?

(a) 1, 2 and 3 only (b) 1, 3 and 4 only
(c) 2 and 4 only (d) 1, 2, 3 and 4 only

*84. What would happen if phytoplankton of an ocean is completely destroyed for some reason?

1. The ocean as a carbon sink would be adversely affected.
2. The food chains in the ocean would be adversely affected.
3. The density of ocean water would drastically decrease.

Select the correct answer using the codes given below.

(a) 1 and 2 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

*85. Vultures which used to be very common in Indian countryside some years ago are rarely seen now-a-days. This is attributed to

(a) The destruction of their nesting sites by new invasive species

(b) A drug used by cattle owners for treating their diseased cattle

(c) Scarcity of food available to them

(d) A widespread, persistent and fatal disease among them

*86. How does National Biodiversity Authority (NBA) help in protecting the Indian agriculture?

1. NBA checks biopiracy and protects the indigenous and traditional genetic resources.
2. NBA directly monitors and supervises the scientific research on genetic modification of crop plants.
3. Application for Intellectual Property Rights related to genetic/biological resources cannot be made without the approval of NBA.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

*87. The National Green Tribunal Act, 2010 was enacted in consonance with which of the following provisions of the constitution of India?

1. Right to Healthy Environment, construed as a part of Right to Life under Article 21.
2. Provision of grants for raising the level of administration in the Scheduled Areas for the welfare of Scheduled Tribes under Article 275(1).
3. Powers and functions of Gram Sabha as mentioned under Article 243(A).

Select the correct answer using the codes given below.

(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

*88. Consider the following kinds of organisms

1. Bacteria 2. Fungi
3. Flowering Plants

Selected species of which of the above kinds of organisms are employed as biopesticides?

(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

*89. The Government of India encourages the cultivation of 'sea buckthorn'. What is the importance of this plant?

1. It helps in controlling soil erosion and in preventing desertification.
2. It is a rich source of biodiesel.
3. It has nutritional value and is well-adapted to live in cold areas of high altitudes.
4. Its timber is of great commercial value.

Which of the statements given above is/are correct?

(a) 1 only (b) 2, 3 and 4 only
(c) 1 and 3 only (d) 1, 2, 3 and 4

*90. Consider the following crops of India:

1. Cowpea
2. Green gram
3. Pigeon pea

Which of the above is/are used as pulse, fodder and green manure?

(a) 1 and 2 only (b) 2 only
(c) 1 and 3 only (d) 1, 2 and 3

*91. The acidification of oceans is increasing. Why is this phenomenon a cause of concern?

1. The growth and survival of calcareous phytoplankton will be adversely affected.
2. The growth and survival of coral reefs will be adversely affected.
3. The survival of some animals that have phytoplanktonic larvae will be adversely affected.
4. The cloud seeding and formation of clouds will be adversely affected.

Which of the statements given above is/are correct?

(a) 1, 2 and 3 only (b) 2 only
(c) 1 and 3 only (d) 1, 2, 3 and 4

92. Consider the following statements about 'Green-Bridge' technology used to clean the polluted lakes:

1. It uses filtration and purification power of fibrous materials like coconut coir or dried water hyacinth, to form the bridge.
2. Energy sources are sun and air.
3. It is an expensive technique.
4. It has recently been used to salvage the famed Udaisagar Lake in Udaipur.

Which of the above given statements are correct?

(a) 1 and 2 only (b) 1, 2 and 3 only
(c) 1, 2 and 4 only (d) All of the above

93. Consider the following sources of energy:

1. Sun
2. Sea waves or tides
3. Wind
4. Coal

Which of the above given energy resources is/are renewable and green source of energy?

(a) 1 only (b) 2 only
(c) 1, 2 and 3 only (d) 1, 2, 3 and 4 only

94. Consider the following statements about Siberian Crane:

1. It is a migratory bird.
2. It visits Keoladeo National Park, in Rajasthan, in winters.
3. It is a white-eyed bird with a scarlet face.
4. It is facing local extinction.

Which of the above given statements are correct?

(a) 1 only (b) 1 and 2 only
(c) 1, 2 and 3 only (d) All of the above

95. Which of the following birds is/are facing extinction?

1. Red-wattled Lapwing
2. Indian Vulture
3. Little Cormorant
4. Pale-crested Cuckoo

Select the correct answer using the codes given below.

(a) 1 only (b) 2 only
(c) 2 and 3 only (d) 1, 3 and 4 only

96. Consider the following statements about the Corbett National Park.

1. It is India's oldest National Park.
2. It is located in Rajasthan.
3. It is the biggest haven for tigers.
4. It is also famous for wild elephants, birds, butterflies and gharials.

Which of the above given statements is/are correct?

(a) 1 and 2 only (b) 1, 2 and 3 only
(c) 1, 3 and 4 only (d) 1, 2, 3 and 4

97. Which of the following techniques is/are deployed for tiger census in India?
    1. E-Eye (Electronic-Eye)
    2. Scat (faecal matter) analysis
    3. Pug-marks
    4. Radio collar/GPS collar

Select the correct answer using the codes given below.

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 4 only (d) 1, 2, 3 and 4

98. Consider the following statements about the Iconic Great Barrier Reef.
    1. It is located in Queensland State of Australia.
    2. It is world's largest reserve of corals.
    3. UNESCO has listed it as an endangered site.
    4. It is under threat from industrial development.

Which of the above given statements is/are correct?

(a) 1 only (b) 1 and 2 only
(c) 1 and 3 only (d) 1, 2, 3 and 4

99. The Indian eastern coastal state of Odisha was recently in news for
    1. Launching of Agni-V
    2. Traumatic tsunami
    3. Olive ridley turtles
    4. Infant mortality due to malnutrition

Select the correct answer using the codes given below.

(a) 1, 2 and 3 only (b) 1 and 3 only
(c) 1, 3 and 4 only (d) 2, 3 and 4 only

100. Consider the following characteristic features of Protected Area (PA).
    1. It is a clearly defined geographical space dedicated and managed to achieve long-term conservation of nature.
    2. It includes government reserved forests.
    3. It comprises wildlife sanctuaries and National Parks.
    4. In these areas human occupation and exploitation of resources is limited.

Which of the above given statements is/are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 1, 3 and 4 only (d) All of the above

101. Consider the following statements about Red list of IUCN:
    1. It is world's most comprehensive inventory of the global conservation status of biological species.
    2. It is reviewed every year.
    3. It assesses the risk of extinction to species.
    4. It's headquarter is located in United States of America.

Which of the above given statements is/are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1 and 4 only

102. Consider the following birds.
    1. Greater Adjutant Storks
    2. Osprey
    3. Cattle Egret
    4. Siberian Crane

Which of the above given birds are long distance migratory birds?

(a) 1 and 2 only (b) 2 and 3 only
(c) 2 and 4 only (d) 3 and 4 only

103. Which of the following statements about 'Noori' is correct?
    (a) It is the name of Indian movie.
    (b) It is the name of an endangered species of sheep.
    (c) It is an extinct species of Kashmiri stag.
    (d) It is world's first cloned Pashmina goat.

104. Consider the names of the following scientists; who among them is known as the "Birdman of India"?
    (a) Dr. Hargobind Khorana

(b) Dr. Salim Ali
(c) Dr. Devi Setty
(d) Dr. J.C. Bose

105. Which of the following is/are "clean and green Fuel"?
1. Petrol
2. Diesel
3. CNG
4. Bio-fuel

Select the correct answer using the codes given below.
(a) 1 and 2 only
(b) 3 only
(c) 4 only
(d) 3 and 4 only

106. Tal Chhapar sanctuary in Churu district of Rajasthan is all set to become a National park. Which of the following condition/s need to be fulfilled for this upgradation?
1. Increasing the size of sanctuary to provide more space and long term conservation to black bucks and a wide variety of resident and migratory birds
2. Acquiring human habitation
3. Restricted use of roads

Select the correct answer using the codes given below.
(a) 1 only
(b) 2 and 3 only
(c) 1 and 2 only
(d) 1, 2 and 3

107. "Green Economy" is the main theme of "World Environment Day". This economy includes
1. Reduce CO_2 emission
2. Adopt 3R's
3. Plant more trees
4. Conserve energy

Select the correct answer using the codes given below.
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1, 2 and 3 only
(d) 1, 2, 3 and 4

108. The elements in life support system are
1. Interrelated
2. Interdependent
3. Interconnected

Select the correct answer using the codes given below.
(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

109.* Biomass gasification is considered to be one of the sustainable solutions to the power crisis in India. In this context, which of the following statements is/are correct?
1. Coconut shells, groundnut shells and rice husk can be used in biomass gasification.
2. The combustible gases generated from biomass gasification consist of hydrogen and carbon dioxide only.
3. The combustible gases generated from biomass gasification can be used for direct heat generation but not in internal combustion engines.

Select the correct answer using the codes given below.
(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

ANSWER KEY

1. (a)	2. (a)	3. (d)	4. (b)	5. (b)	6. (d)
7. (b)	8. (b)	9. (a)	10. (b)	11. (d)	12. (c)
13. (d)	14. (b)	15. (b)	16. (d)	17. (a)	18. (b)
19. (d)	20. (a)	21. (d)	22. (b)	23. (b)	24. (a)
25. (b)	26. (c)	27. (d)	28. (d)	29. (c)	30. (d)
31. (c)	32. (d)	33. (c)	34. (b)	35. (b)	36. (d)

37. (d)
38. (c)
39. (d)
40. (b)
41. (c)
42. (b)
43. (a)
44. (c)
45. (d)
46. (d)
47. (d)
48. (a)
49. (c)
50. (b)
51. (b)
52. (c)
53. (b)
54. (a)
55. (a)
56. (d)
57. (b)
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59. (b)
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61. (d)
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71. (c)
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73. (b)
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89. (c)
90. (d)
91. (a)
92. (c)
93. (c)
94. (d)
95. (b)
96. (c)
97. (d)
98. (d)
99. (b)
100. (c)
101. (b)
102. (c)
103. (d)
104. (b)
105. (d)
106. (a)
107. (d)
108. (d)
109. (c)

CHAPTER TWO

BIODIVERSITY: THE CHEMICAL PERSPECTIVE

Chemical Diversity in Biological Systems

The joy of walking through a forest, experiencing the healing effect of the green trees, enjoying the smell of wild flowers, watching the insects flitting about, and listening to the chirping birds—don't we just love it? It is this biodiversity that we need to protect and take care of in order to let it be an everlasting source of joy. There is an abundance of chemicals in nature, which serve as important nutrients, medicines, and raw materials for a wide variety of products.

A **natural product** is a substance produced by a living organism, which usually has a biological or pharmacological activity. Natural products find use in drug discovery and drug design, and may be extracted from tissues of terrestrial plants, marine organisms or micro-organism fermentation broths. **Chemical diversity** in nature is based on biological and geographical diversity.

A.2.1 BIOACTIVE COMPOUNDS

Bioactive compounds are **extra nutritional constituents** that are present in small amounts in foods. Plant based diets have protective effects on cardiovascular disease (CVD) and cancer. A large number of bioactive compounds have been discovered which vary widely in chemical structure and function. Phenolic compounds including **flavonoids** are found in cereals, legumes, nuts, olive oil, vegetables, fruits, tea, and red wine. They are antioxidants and have good effect on thrombosis and tumorogenesis. Phytoestrogens are present in soy, flax seed oil, whole grains, fruits, and vegetables. They also have antioxidant properties. Hydroxytyrosol in olives and olive oil is an antioxidant. Resveratrol found in nuts and red wine has antioxidant, antithrombotic and anti-inflammatory properties, and inhibits carcinogenesis. Lycopene, an antioxidant **carotenoid** in tomatoes, protects against cancer. Organosulphur compounds in onions and garlic, and monoterpenes in citrus fruits, cherries and herbs have anticarcinogenic actions.

Bioactive compounds have beneficial health effects. Therefore, a diet rich in a variety of fruits, vegetables, whole grains, legumes, oils and nuts is highly recommended.

Important Bioactive Compounds

Alkaloids Alkaloids are naturally occurring chemical compounds containing carbon, hydrogen and nitrogen. They may also contain oxygen, sulphur, chlorine, bromine and phosphorus. They are produced by a large number of organisms like bacteria, fungi, plants and animals. Most alkaloids have a bitter flavour.

Many alkaloids are toxic to other organisms. Most of the known functions of alkaloids are related to protection. For example, presence of alkaloids in the plant prevents insects and animals from eating it. They also regulate plant growth.

Alkaloids are used as medications and as recreational drugs. Examples are the local anesthetic and stimulant—cocaine; the stimulants—caffeine and nicotine; the analgesic—morphine; the antibacterial—berberine; the anticancer compound—vincristine; the antihypertension agent—reserpine; the spasmolysis agent—atropine; the vasodilator—vincamine; and the antimalarial drug—quinine.

Terpenoids Terpenoids are naturally occurring organic chemicals. They consist of five-carbon **isoprene units** assembled and modified in various ways. They are used extensively for their **aromatic qualities** in perfumes and food flavours. They have antibacterial and other pharmaceutical functions and are used in medicines. Terpenoids are responsible for the scent of eucalyptus and lemon grass, and the flavours of cinnamon, cloves, ginger, lemon, orange and peppermint. Well-known examples of terpenoids are citral, menthol and camphor.

Carotenoids Carotenoids are tetraterpenoid (containing 40 carbon atoms) organic pigments in the chloroplasts and chromoplasts of plants and algae, some types of fungi and bacteria. Carotenoids containing oxygen, such as lutein and zeaxanthin, are known as **xanthophylls**. Carotenoids not containing oxygen, such as x-carotene, β-carotene and lycopene are known as **carotenes**. Carotenes contain only carbon and hydrogen.

The most well-known carotenoid is carotene found in carrots, which is responsible for their bright orange colour. Palm oil is the richest source of carotenoids in nature. Carotenes are yellow, orange or red in colour. Xanthophylls are often yellow. Carotenoid pigments in mature leaves are not obvious because of chlorophyll. However, when chlorophyll is not present, as in young foliage and in dying foliage (autumn leaves), yellow, orange and red colours of carotenoids are predominant. These colours also predominate in ripe fruits like oranges, tomatoes and bananas. The pink colour of salmon and the red colour of cooked lobsters is due to carotenoids.

Carotenoids absorb light energy for use in photosynthesis. They have **antioxidant activity** and enhance the vertebrate immune system. Dietary lipids are essential for carotenoid bioavailability. Oils (as lipid sources) enhance carotenoid absorption in humans. Products of carotenoid degradation are the key odour-contributing compounds in flowers, and are used in perfume industry. The sweet floral smells present in black tea, aged tobacco, grapes and other fruits are due to the aromatic compounds resulting from carotenoid breakdown.

Steroids Steroids are organic compounds composed of twenty carbon atoms bonded together in the form of four fused rings. They are found in plants, animals and fungi. Sterols are steroids with a hydroxyl group, e.g., cholesterol. Other examples of steroids: sex hormones like testosterone and progesterone, calciferol, ergosterol, stigmasterol. Most medical steroid drugs are corticosteroids. They regulate metabolism and immune function, some help maintain blood volume and control renal excretion of electrolytes, whereas others increase muscle and bone synthesis. Cholesterol, which modulates the fluidity of cell membranes, is the principal constituent of the plaques deposited in atherosclerosis.

Tannins Tannins are **polyphenols** obtained from various parts of different plants. Tannins are found in abundance in the tree bark, wood, fruit, leaves and roots.

Tannins are used to convert animal hides to leather through chemical processes (tanning). They are also used in dyeing, photography, refining beer and wine, and as an astringent in medicines. They are an important component of tea. They are added to processed foods like ice-cream and caramel.

Tannins lower the absorption of some materials in the body and are, therefore, also known as anti-nutrients. Too much consumption of tea or coffee can result in calcium and iron deficiency and may lead to osteoporosis and anemia. Tannins are used as antidotes to poisoning by alkaloids. They have antiseptic properties and are applied on the skin to heal burns and to stop bleeding. They are applied on the skin to pull out poisons from bee stings. Herbs containing tannins are used as mouthwashes and eyewashes. They are also used to cure diarrhoea.

Tannins also find use as preservatives. They prevent rotting in dry wood and leather. They protect plants by repelling insects and animals. Bacteria and fungi cannot grow on plants containing tannin.

Lignin Lignin is a complex chemical compound obtained from wood. It is an abundant organic polymer. It fills the spaces in the cell wall giving mechanical strength. It plays an important role in conducting water in plant stems. It has a significant role in carbon cycle. It decomposes very slowly and contributes large amounts of humus on decomposition.

Highly lignified wood is durable and serves as a good raw material for many applications. It is an excellent fuel. Pulp used to make newsprint contains lignin.

Flavonoids Flavonoids are **polyphenols** found naturally in plants. They are antioxidants. They have no direct involvement with the growth or development of plants. They are plant nutrients, which when consumed in the form of fruits and vegetables are non-toxic as well as beneficial to the human body. They are widely distributed in plants and are responsible for the vibrant colours of flowers and fruits. They protect the plants from microbes and insects. They trigger the production of enzymes that fight diseases and reduce the risk of cancer, heart disease and age-related degenerative diseases.

Foods rich in flavonoids include blueberries, blackberries, red beans, red and yellow fruits and vegetables, and nuts. Red wine and certain teas also contain flavonoids.

Coumarins Coumarin is a chemical compound found in plants like vanilla grass, sweet grass and sweet clover. It has a pleasant sweet odour, a bitter taste and appetite-suppressing properties.

Biological activities reported for coumarins include anti-HIV, anti-tumor, anti-hypertension, anti-inflammatory, anti-osteoporosis, antiseptic and analgesic. Coumarins are used as anticoagulant drugs and as rodenticides.

A.2.2 FLAVOURS

Flavour is the sensory perception of a substance determined by the sense of taste or smell. The flavour of food can be altered with a natural or artificial flavourant. Flavourant is a substance that gives flavour to another substance, making it sour, sweet, salty, etc. Smell is the main determinant of flavour of a food item. Therefore, the flavour can be easily altered by changing the smell while keeping the taste same. Most commercial flavourants are chemical equivalents of natural flavours which are chemically synthesised rather than being extracted from natural sources.

There are three main types of flavourants:

1. **Natural Flavourants** are obtained from plant or animal raw materials.
2. **Nature-identical Flavourants** are obtained by synthesis, and are chemically identical to naturally occurring flavouring substances.

3. **Artificial Flavourants** are flavouring substances not identified in a natural product. Although they are chemically different, in sensory characteristics they are the same as natural ones.

Thousands of compounds can be used as flavourants and these can also be mixed together to produce specific flavours. Many flavourants consist of esters which have a sweet, fruity odour. Examples of chemicals with different odour:

Chemical	Odour
Isoamyl acetate	Banana
Benzaldehyde	Bitter almond
Cinnamaldehyde	Cinnamon
Limonene	Orange
Allyl hexanoate	Pineapple
Ethyl vanillin	Vanilla

Monosodium glutamate is one of the most commonly used flavour enhancers in food processing. Acids are used to impart a sour taste that alters the flavour of a food. For example, acetic acid gives vinegar its sour taste, citric acid found in citrus fruits gives them their sour taste, lactic acid found in milk or fermented products gives them a rich tartness, malic acid in apples gives them their sour taste, tartaric acid found in grapes and wines gives them a tart taste, and phosphoric acid is used in Cola drinks to give an acid taste.

The colour of food can affect flavour. For example, adding more red colour to a drink increases its sweetness.

A.2.3 FRAGRANCES

An **aroma compound**, also known as **odourant** or **fragrance**, is a chemical compound that has a smell or odour. These compounds are volatile and are found in food, wine, spices, perfumes, and fragrance oils. Many of them form biochemically during ripening of fruits and other crops. In wines, most form as byproducts of fermentation. Chemically, they are generally esters or terpenoids. Examples:

Compound	Fragrance
Esters	
Methyl formate	Ethereal
Methyl acetate	Sweet, nail polish solvent
Methyl butyrate	Apple, Pineapple
Ethyl acetate	Sweet, solvent
Ethyl butyrate	Orange, Pineapple
Isoamyl acetate	Banana, Pear
Terpenoids	
Geraniol	Rose
Nerol	Sweet rose
Citral	Lemon
Citronellal	Lemon
Linalool	Lavender
Limonene	Orange

A.2.4 PHEROMONES

Pheromones are secreted or excreted chemicals that trigger a social response in members of the same species. These chemicals act outside the body of the secreting individual to influence the behaviour of the receiving individual. There are alarm pheromones, food trial pheromones, sex pheromones, and many others. Most insects and some vertebrates and plants communicate by using pheromones.

A.2.5 PORPHYRINS

Porphyrins are a group of organic compounds. Most of them are naturally occurring. They are heterocyclic compounds and consist of macrocycles. The most well known porphyrin is heme, the pigment in red blood cells. Heme is an iron porphyrin and chlorophyll is a magnesium porphyrin. Porphyrin based compounds are of interest in molecular electronics and supramolecular building blocks. Phthalocyanines, which are structurally related to porphyrins, are used as dyes and catalysts. Synthetic porphyrin dyes are used in solar cells. Isolation of porphyrins from petroleum is used to establish the biological origins of petroleum. Petroleum is "fingerprinted" by analysis of trace amounts of nickel and vanadyl porphyrins.

A.2.6 BIOCHEMICAL COMPOUNDS

Biochemistry is the study of chemical processes in living organisms. Biochemical substances are divided into two groups: **bio-inorganic substances** (which include water and inorganic salts), and **bio-organic substances** (which include carbohydrates, proteins, lipids, and nucleic acids). Many biological molecules are polymers.

Carbohydrates

Carbohydrates are the most abundant class of bio-organic molecules on earth. Plants containing green chlorophyll produce carbohydrates via **photosynthesis**. In this process carbon dioxide from air, and water from the soil are the reactants, and sunlight absorbed by chlorophyll is the energy source. In the form of **cellulose**, carbohydrates serve as structural elements, and in the form of **starch**, they provide energy reserves for the plants.

Carbohydrates perform following functions in humans:

- Carbohydrate oxidation provides energy.
- Carbohydrate storage, in the form of glycogen, provides a short term energy reserve.
- Carbohydrates supply carbon atoms for the synthesis of other biochemical substances (proteins, lipids and nucleic acids).
- Carbohydrates form part of the structural framework of DNA and RNA molecules.
- Carbohydrates linked to lipids are structural components of cell membranes.
- Carbohydrates linked to proteins function in a variety of cell-cell and cell-molecule recognition processes.

Examples of carbohydrates: glucose, fructose, galactose, ribose, sucrose, lactose, maltose, starch, glycogen, and cellulose (see details in Chemistry Section D.8.1). Fructose is associated with the sweet taste of fruits. A 5% glucose solution is often used in hospitals as an intravenous source of nourishment for patients who cannot take food by mouth. Two hormones, insulin and glucagon, keep glucose concentration in the blood within the normal range (70–100 mg/dL). Abnormal hormonal functioning leads to diabetes. The glucose content of urine can be determined by dipping a plastic strip treated with oxidising agents like Tollens and Benedict's solution. The problem called **lactose intolerance** is a condition in which people lack the enzyme lactase, which is needed to hydrolyse lactose. So they are not able to digest milk.

Proteins

A protein is a naturally occurring, unbranched polymer in which the monomer units are **amino acids**. Over 700 different naturally occurring amino acids are known but only 20 of them, called **standard amino acids**, are normally present in proteins (see details in Chemistry Section D.8.1).

Ingested proteins are broken up into single amino acids or dipeptides in the small intestine and then absorbed. They can then be joined together to make new proteins. Most bacteria and plants possess the necessary enzymes to synthesise all twenty amino acids. However, humans and other mammals cannot synthesise the following amino acids:

isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.

These are called **essential amino acids**, since it is essential to include them in the diet. Mammals do possess the enzymes to synthesise the following amino acids which are called **non-essential amino acids**: alanine, glycine, asparagine, aspartic acid, glutamine, glutamic acid, cysteine, proline, serine and tyrosine.

Although they can synthesise arginine and histidine, they cannot produce them in sufficient amounts for young, growing animals. Therefore, they are considered essential amino acids.

A complete dietary protein is one that contains all the essential amino acids. It may or may not contain all the non-essential amino acids. Most animal proteins, including casein from milk and proteins found in meat, fish and eggs are complete proteins. Proteins from plants (grains, legumes, and vegetables) have quite diverse amino acid patterns and some have only one or more essential amino acids. Soy is a complete protein.

The sequence of amino acids is different in different proteins. The number of isomeric peptides possible, increases rapidly as the length of the peptide chain increases. For a peptide containing 5 different amino acids, 120 isomers are possible. The three-dimensional shape of proteins is determined by the sequence of amino acids. A single change can change the entire structure. For example, one chain of haemoglobin contains 146 amino acid residues. Substitution of glutamic acid residue at position 6 with a valine residue results in a very serious disease, sickle cell anemia.

Functions of Proteins Proteins play crucial roles in almost all biochemical processes. Their main functions are:

- **Catalysis** - Virtually all the reactions that take place in living organisms are catalysed by proteins called **enzymes**.
- **Structure** - Structural proteins confer rigidity to biochemical systems. Collagen is a component of cartilage. It is found in tendons, and bone. Keratin gives mechanical strength to hair, nails, feathers, hooves, wool and some animal shells.
- **Movement** - Muscle expansion and contraction are involved in every movement we make. Muscles are made up of protein molecules called myosin and actin.
- **Transport** - A large number of proteins perform transportation duties. Haemoglobin carries oxygen from the lungs to other organs and tissues. Transferring carries iron from the liver to the bone marrow. High and low density lipoproteins are carriers of cholesterol in the bloodstream.
- **Hormones** - A number of hormones that regulate body processes are messenger proteins, including insulin, glucagon and human growth hormone.
- **Protection -** Immunoglobulins or antibodies are proteins that bind to foreign substances, such as bacteria and viruses, to help combat invasion of the body by foreign particles. Blood clotting is another protective function carried out by a protein called fibrinogen.
- **Storage** - Ferritin, a protein in the liver, stores iron. Myoglobin is an oxygen-storage protein present in muscles. Casein in milk and ovalbumin in egg white store nutrients for newborn mammals and birds.
- **Regulation -** Some proteins regulate the kind of proteins synthesised in a particular cell, and also dictate when such manufacture takes place.

A typical cell contains about 9000 different proteins; the entire human body has about 100,000 different proteins.

Glycoproteins A glycoprotein is a protein that contains carbohydrates in addition to amino acids. Examples: collagen, and immunoglobulins.

Lipoproteins A lipoprotein contains lipids in addition to amino acids. A **plasma lipoprotein** is involved in the transport of lipids in the bloodstream. There are four major classes of plasma lipoproteins:

1. **Chylomicrons** transport dietary triglycerides from the intestine to the liver and to adipose tissue.
2. **Very-low-density lipoproteins (VLDL)** transport triglycerides synthesised in the liver to adipose tissue.
3. **Low-density lipoproteins (LDL)** transport cholesterol synthesised in the liver to cells throughout the body.
4. **High-density lipoproteins (HDL)** collect excess cholesterol from body tissues and transport it back to the liver for degradation and excretion from the body.

The density of a lipoprotein is related to the fractions of protein and lipid present. The greater the amount of protein, the higher the density of the lipoprotein.

Lipoproteins and Heart Disease Risk

LDL levels correlate directly with heart disease, whereas HDL levels correlate inversely with heart disease risk. Thus HDL is referred to as **"good" cholesterol** and LDL as **"bad" cholesterol**. Reduction in the dietary intake of saturated fat reduces LDL levels. Exercise on a regular basis tends to increase HDL levels. A person's total blood cholesterol level does not necessarily correlate with that individual's real risk for heart and blood vessel disease. A better measure is the **cholesterol ratio**, which is defined as

$$\text{Chlolesterol Ratio} = \frac{\text{Total Cholesterol}}{\text{HDL Cholesterol}}$$

Cholesterol Ratio	Heart Disease Risk
6.0	high
5.0	above average
4.5	average
4.0	below average
3.0	low

Protein Denaturation Protein denaturation is the disorganisation of the characteristic three-dimensional shape of the protein as a result of disruption of its secondary, tertiary and quaternary structures by means of a physical or chemical agent. Examples of agents that cause denaturation: heat, microwave radiation, ultraviolet radiation, violent whipping or shaking, detergent, organic solvents, strong acids and bases, salts of heavy metals, reducing agents.

Examples of denaturation:

- When egg white is poured onto a hot surface, the clear albumin solution changes to a white, jelly like solid.
- Cooking food kills microorganisms, e.g., cooking denatures the protein of parasites present in ham or bacon.
- In surgery, heat is often used to seal small blood vessels. This process is called cauterisation.
- Heat induced denaturation is used in sterilising surgical instruments, and in canning foods. Bacteria are destroyed when heat denatures their protein.
- Ultraviolet radiation from the sun denatures skin proteins and causes sunburn.
- Formation of yogurt, and curdling of milk to make cheese result from the presence of lactic acid, a by-product of bacterial growth.
- Denaturation of bacterial protein takes place when alcohol is used as a disinfectant. That is why swabbing the skin with alcohol before giving an injection is a common practice.
- The processes of permanent waving and straightening of curly hair involve the use of reducing agents, like 2-mercaptoethanol, to denature hair.

- Raw egg whites and milk serve as antidotes for heavy metal poisoning. The egg and milk proteins are denatured by metal ions (Pb^{2+}, Hg^{2+} and Cd^{2+}), and form insoluble precipitates in the stomach, which are pumped out or removed by inducing vomiting.
- Protein denaturation is used in **laser surgery**. A laser beam is absorbed by tissues, and its energy is converted to heat energy. This process can be used to cauterise incisions so that a minimal amount of blood is lost during the operation. Laser technology is also being used to treat tumours and to correct eyesight (**LASIK procedure**).

Lipids

A lipid is an organic compound found in living organisms that is insoluble (or sparingly soluble) in water but soluble in non-polar organic solvents.

On the basis of their functions, lipids can be divided into five categories:

1. Energy-storage lipids (**triglycerides**)
2. Membrane lipids (**phospholipids, sphingoglycolipids** and **cholesterol**)
3. Emulsification lipids (**bile acids**)
4. Messenger lipids (**steroid hormones** and **eicosanoids**)
5. Protective-coating lipids (**biological waxes**)

Fatty acids are structural components of all the lipids except cholesterol, bile acids and steroid hormones. A fatty acid is a naturally occurring monocarboxylic acid. Fatty acids nearly always contain an even number of carbon atoms and have a carbon chain that is unbranched. Fatty acids are classified as:

1. Saturated fatty acids (**SFAs**) (containing only carbon-carbon single bonds) Examples: palmitic acid, stearic acid.
2. Mono-unsaturated fatty acids (**MUFAs**) (containing one carbon-carbon double bond) Example: oleic acid.
3. Poly-unsaturated fatty acids (**PUFAs**) (containing two or more carbon-carbon double bonds) Example: linoleic acid, linolenic acid.

Several different families of unsaturated fatty acids exist on the basis of the double-bond position relative to the methyl end of the fatty acid carbon chain. An unsaturated fatty acid with its endmost double bond three carbon atoms away from its methyl end is called an **omega-3 fatty acid** (ω-3 fatty acid) (e.g.,linolenic acid) and one which has this double bond six carbon atoms away is called **omega-6 fatty acid** (ω-6 fatty acid)(e.g. linoleic acid).

Fats and Oils Fats and oils are naturally occurring complex mixtures of triglycerides, the energy storage lipids. A triglyceride is a triester formed by the esterification of glycerol with three fatty acid molecules. Fats mainly contain saturated fatty acids, whereas oils mainly contain unsaturated fatty acids. Saturated fats are **"bad fats"**, monounsaturated fats are **"good fats"**, and polyunsaturated fats can be both "good fats" and "bad fats". Saturated fats can increase heart disease risk, monounsaturated fats can decrease both heart disease and breast cancer risk, and polyunsaturated fat can reduce heart disease risk but promote the risk of certain types of cancers. Dietary fats high in "good" monounsaturated fatty acids (MUFAs) include olive, avocado, and canola oils. MUFAs help reduce the stickiness of blood platelets. This helps prevent the formation of blood clots and may also dissolve clots once they form. Fats rich in PUFAs are safflower, sunflower, corn, soyabean, and cottonseed oil. Butterfat and coconut oil contain large amounts of SFAs.

Eating nuts can have a strong protective effect against coronary heart disease. Nuts rich in MUFAs are hazelnuts, pistachios and almonds. Walnuts are rich in PUFAs. The unsaturation/saturation ratio is highest for hazelnuts, walnuts, and almonds and lowest for cashews. Nuts also offer valuable antioxidant vitamins, minerals, and plant fiber protein. The active chemical component in the anticancer drug taxol is found in hazelnuts.

Fish like mackerel, tuna and salmon have a positive effect on heart health as they contain more omega-3 acids.

An **essential fatty acid** is one that is needed in the human body and must be obtained from dietary sources because it cannot be synthesised within the body, in adequate amounts, from other substances. There are two essential fatty acids: linoleic acid (omega-6 acid), and linolenic acid (omega-3 acid). These two acids are needed for proper membrane structure. They serve as starting materials for the production of several nutritionally important longer-chain omega-6 and omega-3 acids, which are required for regulation of blood pressure, clotting of blood, normal brain development, and several other important body functions.

Several types of **"artificial fats"** have been developed which have the taste, texture and cooking properties of fats but are themselves not lipids.

Peanut butter is produced from peanut oil through partial hydrogenation. Solid cooking shortenings and soft-spread margarines are also partial hydrogenation products. This hydrogenation process converts some cis-double bonds in fatty acid residues into trans-double bonds. These **trans-fats** play a role in raising blood cholesterol levels. Trans-fats are also present in crackers, cookies, pastries and deep fried fast foods. Trans-fat raises bad (LDL) cholesterol, but it does not raise good (HDL) cholesterol. Saturated fat, on the other hand, raises both bad and good cholesterol.

Rancidity The double bonds in fats and oils are subject to oxidation by the air. When a fat or oil is allowed to stand out in the open, this reaction slowly turns some of the molecules into aldehydes and other compounds with foul tastes and odours. The resulting product is called a **rancid** oil or fat and is no longer edible. Another cause of unpleasant taste (rancidity) is hydrolysis. The hydrolysis of triglycerides may produce short-chain fatty acids, which have unpleasant odours. To prevent rancidity, fats and oils should be kept refrigerated and in dark bottles. Antioxidants are added to fats and oils to prevent rancidity.

Waxes Plant and animal waxes are simple esters formed from long chain alcohols and fatty acids. Animals and plants use them for protective coatings. The leaves of most plants are coated with wax, which helps to prevent microorganisms from attacking them and allows the plants to conserve water. The feathers of birds and the fur of animals are also coated with wax. Important waxes include carnauba wax (from Brazilian palm tree), lanolin (from lamb's wool), and beeswax. They are used to make cosmetics, polishes, candles and ointments. Ear wax is a mixture of fats (triglycerides), phospholipids and esters of cholesterol.

Bile Acids Cholesterol derivatives called bile acids function as emulsifying agents that facilitate the absorption of dietary lipids in the intestine.

Cholesterol Cholesterol is the most abundant, and important steroid in the human body. It exists both in the free form and esterified with fatty acids. Gallstones contain free cholesterol.

Nucleic Acids

Each cell of our body contains thousands of different protein molecules. **Heredity** is the transfer of characteristics from generation to generation. This transfer takes place in the nucleus of the cell. Nuclei are largely made up of special proteins called **histones** and **nucleic acids** (see details in Chemistry Section D.8.1).

Two kinds of nucleic acids are found in cells: **ribonucleic acid (RNA)** and **deoxyribonucleic acid (DNA)**. Nucleic acids are polymers of **nucleotides**, which themselves are composed of three simpler units: a base, a monosaccharide (sugar), and a phosphate. The combination of sugar and base is known as a **nucleoside**. When a phosphate unit combines with a nucleoside, the product is a nucleotide.

Nucleotides play important roles in metabolism. They are part of the structure of key coenzymes, cofactors and activators. Most notably, **adenosine triphosphate (ATP)** serves as a common currency into which the energy gained from food is converted and stored. RNA with catalytic activity is called a **ribozyme.**

A.2.7 ENZYMES

Enzymes are macromolecules that catalyse chemical reactions in biological systems. Most enzymes are very specific; they catalyse only one particular reaction. The compound whose reaction is catalysed by an enzyme is called the **substrate**. Most enzymes are proteins, although some are made of RNA.

There are six classes of enzymes based on functions: oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases. Some enzymes are made of proteins only. Others have, besides the protein (**apoenzyme**), nonprotein **cofactors**, which are either organic compounds (**coenzymes**) or inorganic ions. Only a small part of the enzyme surface, called the **active site**, participates in the actual catalysis of chemical reactions. Compounds that slow down enzyme action are called **inhibitors**. Each enzyme has an optimal temperature and pH at which is has its greatest activity. Enzymes lose their biological activity on denaturation. A person suffering from high fever (greater than 106°F) runs the risk of denaturing certain enzymes.

Yeast enzymes are used in the production of bread. Fermentation of sugars in fruit juices with yeast enzymes produces alcoholic beverages.

Some examples of enzymes: trypsin, chymotrypsin, pepsin, lactase, urease, maltase and sucrase.

Fruits such as apples, pears, peaches, apricots and bananas and vegetables such as potatoes quickly turn brown when their tissue is exposed to oxygen. This browning is related to the work of phenolase, an enzyme in which copper is present.

An antibiotic is a substance that kills bacteria or inhibits their growth. Antibiotics usually inhibit specific enzymes essential to the life processes of bacteria.

A.2.8 IMMUNOGLOBULINS

Immunochemistry is a branch of chemistry that deals with the study of the reactions and components of the immune system.

The basic molecules of the immune system are **immunoglobulins**. An immunoglobulin is a glycoprotein produced by an organism as a protective response to the invasion of microorganisms or foreign molecules. Immunoglobulins serve as antibodies to combat invasion of the body by antigens. An **antigen** is a foreign substance, such as a bacterium or virus, that invades the human body. An **antibody** is a biochemical molecule that counteracts a specific antigen. The immune system of the human body has the capacity to produce immunoglobulins that respond to several million different antigens. An immunoglobulin combines with the invading antigen to produce an antigen (antibody complex) which precipitates and gets eliminated from the body.

The AIDS (Acquired Immuno Deficiency Syndrome) virus upsets the body's normal production of immunoglobulins and leaves the body susceptible to infections. Individuals who receive organ transplants are given drugs to suppress the production of immunoglobulins against foreign proteins in the new organ, thus preventing rejection of the organ.

It is important for a mother to breast-feed a newborn infant. During the first few days of lactation, the breasts produce colostrum, a premilk substance containing immunoglobulins from the mother's blood. Colostrum helps protect the body from those infections to which the mother has developed immunity.

A.2.9 PHARMACEUTICAL DRUGS

A pharmaceutical drug, also known as **medicine** or **medication**, is defined as a chemical substance used in the medical diagnosis, treatment, or prevention of disease. Drugs are obtained from a variety of natural sources or created synthetically in the laboratory (see details in Chemistry Section D.9.1).

A.2.10 VITAMINS

Vitamins are a class of nutrients that cannot be biosynthesised by the human body (except vitamins D and K) and must be obtained from the diet. They are essential for the normal functioning of the body. Human body needs small amounts of vitamins in balanced proportions. Deficiency of particular vitamins causes specific diseases. Treatment of these deficiency diseases by supplementing the diet with necessary vitamins is known as vitamin therapy. An excess of vitamins may cause side effects (hypervitaminosis).

Classification of Vitamins

On the basis of their solubility, vitamins are broadly divided into fat soluble vitamins and water-soluble vitamins (see Table A.2.1). Extra amounts of fat-soluble vitamins are stored in the fatty tissues, especially in the liver; water- soluble vitamins cannot be stored in the body and tend to be excreted.

List of Vitamins

Vitamin A, B_1, B_2, B_3, B_5, B_6, B_9, B_{12}, C, D, E, H, K and P.

Water soluble vitamins are destroyed by overcooking. They are easily washed out during food storage and preparation.

Table A.2.1

Vitamins

	Vitamin	Biochemical Function	Deficiency Effects	Sources
		Fat-soluble vitamins		
1.	Vitamin A (Retinol)	Protects eyes, prevents night blindness	Light sensitivity, night blindness	Fish, liver, eggs, butter cheese, carrots
2.	Vitamin D (Calciferol)	Essential in building strong bones	Rickets	Cod liver oil, spinach, sunlight
3.	Vitamin E (α-Tocopherol)	Antioxidant, maintains RBC membranes	Oedema, anemia, sterility	Egg yolk, meat, nuts, green vegetables, wheatgerm oil
4.	Vitamin K (Phylloquinone)	Aids in clotting of blood	Slow clotting of blood	Cauliflower, leafy vegetables
		Water-soluble vitamins		
1.	Vitamin B_1 (Thiamine)	Carbohydrate metabolism, proper functioning of heart	Beri-beri	Milk, nuts, cereal grains, legumes
2.	Vitamin B_3 (Niacin)	Metabolism of proteins, carbohydrates and fats	Pellagra	Yeast, liver, peanuts, soyabeans, potatoes
3.	Vitamin B_5	Synthesis of heme, fatty acids, amino acids, cholesterol	Retarded growth	Yeast, mushrooms, egg-yolk, nuts, liver
4.	Vitamin B_6	Production of antibodies	Increased susceptibility to infections	Egg, liver, yeast, peas, beans, milk
5.	Vitamin B_9 (Folic acid)	Formation of red blood cells	Anemia	Liver, kidney, mushrooms, yeast, green leafy vegetables
6.	Vitamin C (Ascorbic acid)	Resists disease, protects bones, teeth and gums, heals wounds	Scurvy	Citrus fruits, tomatoes, green pepper, cabbage, cauliflower

A.2.11 HORMONES

A hormone is a biochemical substance, produced by a ductless gland (**endocrine gland)**, that has a messenger function. Hormones serve as a means of communication between various tissues. Plant hormones are also called **phytohormones**.

Hormones have the following effects on the body:

- mood swings
- stimulation or inhibition of growth
- activation or inhibition of the immune system
- regulation of metabolism
- preparation of the body for a new phase of life, such as puberty, parenting and menopause
- control of the reproductive cycle
- hunger cravings

A hormone may also regulate the production and release of other hormones. The thyroid-stimulating hormone (TSH) causes increased activity of the thyroid gland.

Vertebrate hormones fall into three chemical classes:

- **Peptide hormones** consist of chains of amino acids. Vasopressin is a peptide hormone. Examples of protein hormones include insulin and growth hormone. Follicle stimulating hormone and thyroid stimulating hormone are examples of **glycoprotein hormones** (complex protein hormones with carbohydrate side-chains).
- **Lipid and phospholipid derived hormones** include **steroid hormones** like testosterone and cortisol, and **eicosanoids** like prostaglandins.
- **Monoamines**—Thyroxine and adrenaline are examples of monoamines.

Many hormones are used as medication. Thyroxine is prescribed for hypothyroidism and steroids for several respiratory disorders. Insulin is used by many diabetics. Steroid creams are used in dermatological practice.

A.2.12 NEUROTRANSMITTERS

Neurotransmitters are chemicals located and released in the brain to allow an impulse from one nerve cell to pass to another nerve cell. Nerve cells do not directly touch each other. They communicate messages by secreting neurotransmitters. Some common neurotransmitters are acetylcholine, norepinephrine, dopamine, serotonin and gama aminobutyric acid (GABA).

Norepinephrine, secreted by the adrenal glands, helps maintain muscle tone in the blood vessels. Impairment of dopamine containing nerve cells in the brain is implicated in schizophrenia, a mental disease. Deficiency of dopamine, found in the brain, results in Parkinson's disease. Drug L-dopa gives relief from Parkinson's symptoms. Serotonin, also a brain chemical, is involved in sleep, sensory perception and the regulation of body temperature. Serotonin deficiency has been implicated in mental illness. Prozac, the most widely prescribed drug for mental depression, maintains serotonin levels. Alzheimer's disease is caused by a loss of cells that secrete acetylcholine in the brain. There is a correlation between personality disorders and neurotransmitter imbalance. Alcohol causes its effects by interacting with the GABA receptor.

CHEMICAL THREATS TO BIODIVERSITY

Chemistry has brought about a medical revolution which resulted in the average life expectancy rising from 47 in 1900 to 75 in the 1990s. The explosive expansion of world's food supply has been because of development of chemicals that protect crops and enhance growth. In almost every area (food, clothing, shelter, transportation, communication, etc.) chemistry has brought about an improvement in the quality of life of people.

We, however, have paid a very heavy price for these unbelievable achievements. That price is the toll which the manufacture, use and disposal of synthetic chemicals have taken on human health and the environment. The Toxics Release Inventory (TRI), USA, established under the Emergency Planning and Community Right-to-Know Act, tracks the release of chemicals by different sectors of industry. Of the top ten industrial sectors tracked by the TRI, the chemical industry releases a greater amount of waste to the environment than the other nine industrial sectors combined.

A.2.13 CHEMICAL TOXICOLOGY

There are various chemicals in the environment, some of which are toxic. These toxic chemicals are released by industries into air, water and soil. They upset the complex system of chemical reactions occurring in the human body. They can cause discomfort, illness, disability or even death. **Chemical Toxicology** is the science of the study of toxic chemicals and their modes of action.

Toxic Chemicals in Air

Some of the extremely hazardous substances in the atmosphere are acrylonitrile, arsenic, asbestos, benzene, beryllium, cadmium, chlorinated solvents, chlorofluorocarbons, chromates, coke oven emissions, ethylene dibromide, ethylene oxide, lead, mercury, ozone, sulphur dioxide, vinyl chloride and toxic waste disposal emissions.

Toxic Chemicals in Water

The toxic elements found in natural and waste waters are arsenic, cadmium, beryllium, boron, chromium, copper, fluorine, lead, manganese, mercury, molybdenum, selenium and zinc. The water bodies contain pesticides, mainly from the drainage of agricultural land.

Effect of Toxic Chemicals on Enzymes

Toxic chemicals attack enzymes, inhibiting their essential function. Heavy metal ions like Hg^{2+}, Pb^{2+} and Cd^{2+} act as effective enzyme inhibitors.

Classification of Toxic Substances

1. Corrosive Poisons Corrosive poisons are toxic substances which **destroy tissues**, e.g., strong acids and alkalies, and many oxidants which can destroy tissues (see Table A.2.2). Concentrated mineral acids such as sulphuric acid and bases like sodium hydroxide attack cellular structures. The cell dies because the proteins are hydrolysed by the acid or the base.

Some poisons undergo chemical reactions in the body to produce corrosive poisons. When phosgene (the deadly gas used during World War I) is inhaled, it gets hydrolysed in the lungs to hydrochloric acid, which has a dehydrating effect on the tissues. The victim dies of suffocation because oxygen cannot be absorbed effectively by the damaged tissues.

Substances such as ozone, nitrogen dioxide and iodine destroy enzymes by oxidising their functional

Table A.2.2

Corrosive Poisons

	Substance	Possible Contact
1.	Hydrochloric acid	Tile and concrete floor cleaner, used to adjust acidity of swimming pools
2.	Sulphuric acid	Auto batteries
3.	Phosgene	Combustion of chlorine containing plastics (PVC or Saran)
4.	Sodium hydroxide	Drain cleaners
5.	Sodium phosphate	Detergents, household cleaners
6.	Sodium perborate	Laundry detergents, denture cleaners
7.	Ozone	Air, electric motors
8.	Nitrogen dioxide	Polluted air, automobile exhaust
9.	Iodine	Antiseptic
10.	Hypochlorite ion	Bleach
11.	Peroxide ion	Bleach, antiseptic
12.	Oxalic acid	Bleach, leather tanning, spinach, tea
13.	Sulphite ion	Bleach
14.	Nitrosyl chloride	Mixing household ammonia and bleach

groups, or they break chemical bonds in the enzyme leading to its deactivation.

Nitrogen Dioxide

Inhalation of nitrogen dioxide containing gases from burning celluloid and nitrocellulose film lead to death. Accidental release of nitrogen dioxide while loading into a Titan II Intercontinental missile at Rock, Kansas, in 1978, led to two deaths. Nitrogen dioxide disrupts cellular enzyme systems.

Sulphur Dioxide

The main effect of sulphur dioxide is on the respiratory tract. Combination of sulphur dioxide and smoke can prove fatal as in the sulphur dioxide poisoning cases in Belgium (1930), Pennsylvania, USA (1948), London (1952, 1956 and 1957). It is the most serious air pollutant. It is injurious to plants and leads to destruction of leaves. Sulphur dioxide also causes acid rains.

Ozone and PAN

Both ozone and peroxyacetyl nitrate (PAN) are products of photochemical smog. They cause irritation of the eyes and the respiratory tract. They are also harmful to plants and animals. They inhibit the activity of enzymes.

2. Metabolic Poisons Metabolic poisons cause illness or death by interfering with a vital **biochemical mechanism** to such an extent that it ceases to function or does not function efficiently. Some of them are discussed here.

Carbon Monoxide

Carbon monoxide deprives body cells of oxygen (**asphyxiation**). It reacts with haemoglobin to give a compound (carboxyhaemoglobin) which is 140 times more stable than the compound of haemoglobin and oxygen (oxyhaemoglobin). As haemoglobin is so tightly bound to carbon monoxide, it cannot perform its vital function of transporting oxygen.

An organic substance that undergoes incomplete combustion liberates carbon monoxide, e.g., smoldering leaves, lighted cigars or cigarettes, charcoal burners, and auto exhausts. Carbon monoxide poisoning leads to loss of awareness and judgement, metabolic disorders and even death. Smokers suffer chronically from its effects. It is a subtle poison, since it is odourless and tasteless.

Carbon monoxide poisoning can be cured by exposing the affected person to fresh oxygen.

Cyanide

Cyanide occurs in seeds of fruits like apples, apricots, cherries, peaches and plums. It enters the environment from different sources. HCN is used as a fumigating agent to destroy rodents. It is used in many chemical syntheses and in electroplating. It inhibits the action of oxidative enzymes.

Oxidases are enzymes containing a metal, usually iron or copper. They catalyse the oxidation of substances such as glucose. The cyanide ion forms stable cyanide complexes with the metal ion of the oxidase and renders the enzyme inactive. Plenty of oxygen reaches the cells, but the mechanism by which the oxygen is used in the support of life is stopped. Hence the cell dies. If this occurs at a fast rate in the vital centres, the victim dies.

The body has a mechanism for ridding itself slowly of cyanide ions. Other enzymes such as rhodanase, found in almost all cells, can convert cyanide ions to relatively harmless thiocyanate ions (if the dose of cyanide ions is small).

Fluoroacetic Acid

Sodium fluoroacetate (the sodium salt of fluoroacetic acid) is a potent rodenticide (rat poison). Fluoroacetate is toxic because it enters the Krebs Cycle, producing fluorocitric acid, which in turn blocks the Krebs Cycle by combining with an enzyme. **Krebs Cycle** is the process of glucose metabolism which leads to the production of carbon dioxide, water, and energy (in the form of ATP molecules).

Heavy Metals

Heavy metals are the most common of all the metabolic poisons. Most heavy metals are cumulative poisons, i.e., their effects add up. They owe their toxicity primarily to their ability to react with and inhibit sulph-hydryl (-SH) enzyme systems, such as those involved in the production of cellular energy.

(a) Arsenic

Arsenic occurs in insecticides, fungicides and herbicides. It attacks enzymes and inhibits their action. At high concentrations it coagulates proteins.

(b) Cadmium

Excessive amounts of cadmium cause kidney problems, anaemia and bone marrow disorders. The outbreak of cadmium poisoning occurred in Japan in the form of *itai itai* disease in which the bones of victims became fragile.

(c) Lead

Lead is an abundant metal in nature as well as in the atmosphere. The major source of lead in air is the combustion of leaded petrol. Lead often occurs in foods, beverages, public water supplies and even air. Lead not only resides in the soft tissues of the body but is also deposited in bones. Lead can be absorbed through the skin. Cases of lead poisoning have resulted from repeated handling of lead foils, bullets and other lead objects. The major biochemical effect of lead is the disruption of the synthesis of haemoglobin. Higher levels of lead in the blood cause anaemia, kidney dysfunction and brain damage.

Ethylenediaminetetraacetic acid (EDTA) is an effective chelating agent used to remove lead from the human body. A chelating agent combines with an atom or ion to form a complex. EDTA combines with lead ions to form a complex which is excreted in the urine.

(d) Mercury

Mercury is quite volatile and easily absorbed through the skin. Mercury and its salts accumulate in the body which can lead to chronic poisoning. Mercury poisoning is a potential hazard to those working with or near this metal or its salts, such as dentists (who use it to make amalgams for fillings), medical and scientific laboratory personnel and some agricultural workers.

Mercury can also be a hazard when present in food. It enters the food chain through small organisms that feed at the bottom of water bodies that contain mercury from industrial waste or mercury minerals in the sediment. These are eaten by small fish, which in turn are eaten by larger fish. Thus, the poison keeps accumulating as the food chain progresses.

The toxicity of mercury came to limelight after the incidence of 'Minamata disease' in 1953 in

Japan. Cases of mercury poisoning were reported among people who had eaten mercury contaminated fish from Minamata Bay. In Iraq, in 1972, people died after eating wheat which had been dusted with a mercury containing pesticide. Mercury vapour, when inhaled, enters the brain through the blood stream, leading to severe damage of the central nervous system.

3. Neurotoxins Some metabolic poisons limit their action to the **nervous system**. These include poisons such as strychnine and curare. Neurotoxins act at the point where two nerve fibres come together (called a **synapse**).

Neurotoxins such as atropine and curare occupy the receptor sites on nerve endings of organs that are normally occupied by the impulse carrying acetylcholine. When atropine or curare occupies the receptor site, no stimulus is transmitted to the organ. Neurotoxins of this type are useful in medicines. For example, atropine is used to dilate the pupil of the eye to facilitate examination of its interior. When applied to the skin, atropine salts relieve pain by deactivating sensory nerve endings on the skin. Curare is used as a muscle relaxant. Nicotine is a natural compound that blocks receptor sites as is done by atropine and curare. This powerful poison causes stimulation and then depression of the central nervous system. Nicotine is present in tobacco and insecticides.

Natural or synthetic morphine is the most effective pain killer known. It is used to relieve short-term acute pain resulting from surgery, fractures, burns, etc. It is also used to reduce suffering in the later stages of terminal illnesses such as cancer. Under federal law, some preparations containing small amounts of narcotic drugs may be sold without a prescription (e.g., cough syrups containing codeine).

Drugs like morphine, heroin, meperidine and methadone are abused and illicitly used. Heroin is prepared by treating morphine (found in opium poppy) with acetic anhydride. Codeine is also present in opium and is a pain killer. Meperidine and methadone are synthetic products. Caffeine (found in coffee, tea and cola drinks) and cocaine are also neurotoxins.

Pesticides

The most common pesticide, DDT, attacks the central nervous system of insects. It is fairly stable and persists in the environment. Many species of hunting birds, with high levels of DDT, are threatened with extinction. Methyl isocyanate (MIC) is the raw material for the production of carbamate pesticide. Workers exposed to MIC suffer from chest tightness and breathing troubles. According to the findings of the World Health Organisation, about 750,000 people are poisoned by pesticides every year.

4. Mutagens Mutagens are chemicals that can change the genes and chromosomes (**hereditary pattern**) to cause abnormalities in the offspring. They alter the structures of DNA and RNA, which compose the genes that transmit the traits of parent to offspring.

Nitrous acid is a potent mutagen in bacteria, viruses, moulds and other organisms. It reacts with nitrogenous bases of DNA to produce new compounds. The result is an alteration in the genetic coding of DNA, so that a different protein is formed. Sodium nitrite is used as a preservative, colour enhancer or colour fixative in meat and fish products. Sodium nitrite is converted to nitrous acid by hydrochloric acid in the human stomach. Some examples of mutagens: Aflatoxin (from mould), Benzo (α) pyrene (from cigarette and coal smoke), Caffeine, Captan (a fungicide), Chloroprene, Dimethyl sulphate (used for methylation), LSD (lysergic acid diethylamide), Maleic hydrazide (plant growth inhibitor), Mustard gas (dichlorodiethyl sulphide), Ozone, solvents in glue (like toluene, acetone, cyclohexane, hexane and ethyl acetate), and TEM (triethylene melamine, an anticancer drug).

5. Teratogens The chemicals which affect **reproduction** are called teratogens. The study of birth defects produced by chemical agents is called **Teratology**. There are three known classes of teratogens: radiation, viral agents and chemical substances.

Any chemical that can cross the placenta is a potential teratogen. Smoking a cigarette results in higher-than-normal blood levels of such substances as carbon monoxide, hydrogen cyanide, cadmium, nicotine and benzo (α) pyrene. Many of these substances are present in polluted air as well. Other examples of teratogens: Arsenic, Cobalt, Gallium, Lead, Lithium, Mercury, Thallium, Zinc, Caffeine, DES (diethyl stilbestrol) and PCBs (polychlorinated biphenyls).

The horrible thalidomide disaster in West Germany, Great Britain and United States (1961) brought to notice chemically induced birth defects. Thalidomide (a tranquilizer and sleeping pill) caused deformities (flipperlike arms, shortened arms, no arms or legs, and other defects) in children whose mothers used it during pregnancy.

6. Carcinogens Carcinogens are chemicals that cause **cancer** in animals and humans. An abnormal growth is classified as cancerous or malignant when examination shows it is invading neighbouring tissue. A growth is said to be **benign** if it is localised at its original site.

Some compounds cause cancer at the point of contact. Other compounds cause cancer in an area remote from the point of contact. The liver, the site at which most toxic chemicals are removed from the blood, is particularly susceptible to such compounds.

Many molecular structures produce cancer, whereas closely related ones do not, e.g., 2-naphthylamine is carcinogenic whereas 1-naphthylamine is not.

Cancer might be caused if the carcinogen combines with growth control proteins, rendering them inactive. Thus, cells continue to divide and portions of the organism continue to grow. Another possibility is that carcinogens affect DNA, preventing it from giving the necessary directions for the synthesis of substances that control cell growth.

The carcinogenic compounds nitrosodimethylamine and mustard gas react with nucleic acids. Approximately 80% of all human cancer has its origin in carcinogenic chemicals (see Table A.2.3). Smoking is associated with over 20% of all cancers, and asbestos with 3–18%.

Table A.2.3

Chemicals Carcinogenic for Humans

	Compound	Use or Source	Affected site
1.	Arsenic and its compounds	Insecticides, alloys	Skin, lung, liver
2.	Asbestos	Insulation	Respiratory tract
3.	Beryllium	Alloy with copper	Bone, lung
4.	Cadmium	Metal plating	Kidney, lung
5.	Chromium	Metal plating	Lung
6.	Benzene	Solvent, used for synthesis of organic compounds	Blood (leukemia)
7.	Acrylonitrile	Monomer	Colon, lung
8.	Aflatoxins B_1	Mould or peanuts	Liver
9.	Carbon tetrachloride	Solvent	Liver
10.	Diethylstilbestrol	Hormone	Female genital tract
11.	Benzo (α) pyrene	Cigarette and other smoke	Skin, lung
12.	Benzidine	Dye manufacture	Bladder
13.	Ethylene oxide	Used to make ethylene glycol and synthetic detergents	Gastrointestinal tract
14.	Soots, tar and mineral oils	Roofing tar, chimney soot, hydrocarbon oils	Skin, lung, bladder
15.	Vinyl chloride	Monomer for making PVC	Liver, brain, lung, lymphatic system

Table A.2.4

Hallucinogens

	Chemical	Aliases	Active Compound
1.	LSD (very powerful hallucinogen)	Acid, Crackers, The chief, The hawk	Lysergic acid diethylamide
2.	Mescaline	Peyote	3,4,5-Trimethoxy-phenethylamine
3.	Marihuana	Grass, Pot, Hash, Mary Jane	3,4-Tetrahydro-cannabinol
4.	Phencyclidine (powerful analgesic- anesthetic)	PCP, Hog, Elephant, Peace pills, Angel dust	Phencyclidene
5.	Methaqualone (hypnotic)	Quaalude, Ludes	Methaqualone

7. Hallucinogens Hallucinogens (see Table A.2.4) can produce temporary changes in perception, thought and mood. They destroy one's sense of judgement. LSD has been linked with birth defects.

8. Alcohols Methyl alcohol is highly poisonous and is a cumulative poison in human beings. It has a toxic effect on the optic nerve and large doses can cause blindness. In the body, it gets oxidised first to formaldehyde and then to formic acid, which is eliminated in the urine. The toxic effect on the optic nerve is caused by the oxidative products.

Ethyl alcohol (found in alcoholic beverages) is toxic and is absorbed by the gastrointestinal tract. It is oxidised to carbon dioxide and water in the liver. The staggering gait, nausea, etc. of the intoxicated person are caused by the presence of acetaldehyde formed by the oxidation of ethyl alcohol in the liver. The compound disulfiram (Antabuse) is sometimes given as a treatment for **chronic alcoholism** because it blocks the oxidative steps beyond acetaldehyde. The accumulation of acetaldehyde causes nausea, vomiting, blurred vision, and confusion. This prompts the person to prevent this severe sickness by avoiding alcohol.

A.2.14 ENVIRONMENTAL POLLUTION

Pollution is the introduction of contaminants into the environment that cause harm or discomfort to humans or other living organisms, or that damage the environment.

India has been ranked as the seventh most environmentally hazardous country in the world. Brazil is the worst, United States is second worst and China is third. Singapore has been found to be the best.

There are three major types of environmental pollution:

- Air Pollution
- Water Pollution
- Soil Pollution

Air Pollution

Some of the most important air pollutants are sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone, volatile organic compounds (VOCs) and airborne particles. Radioactive pollutants are the most destructive ones specially when produced by nuclear explosions.

Carbon dioxide and water vapour present in the atmosphere, strongly absorb a large fraction of the earth's emitted radiation. This absorbed radiation is partly re-emitted to the earth's surface. The net result is that the earth's surface gets heated up by a phenomenon called the **Greenhouse Effect**. Deforestation and combustion of fossil fuels (oil, gas, coal) have a cumulative effect on the net increase in carbon dioxide content. Forests are the areas where a great deal of photosynthesis occurs, which helps in maintaining a balance in the atmospheric carbon dioxide level.

Table A.2.5

Sources of atmospheric trace gases

	Gas	Major Pollution Sources	Natural Sources
1.	Sulphur dioxide	Combustion of coal and oil	Volcanoes
2.	Hydrogen sulphide	Chemical processes, sewage treatment	Volcanoes, biological action in swamp areas
3.	Carbon monoxide	Auto exhaust and other combustion	Forest fires
4.	Nitrogen dioxide	Combustion	Lightning, bacterial action in soil
5.	Ammonia	Sewage treatment	Biological decay
6.	Hydrocarbons	Combustion exhaust, Chemical processes	Biological processes
7.	Carbon dioxide	Combustion	Biological decay, release from oceans.

Trees and animals contribute large quantities of hydrocarbons (mainly methane) to the atmosphere. Harmful effects of hydrocarbon pollution are due to the photochemical reactions in which they are involved. Large quantities of automobile exhausts in the atmosphere exposed to intense sunlight leads to the formation of photochemical oxidants. This gives rise to **photochemical smog** (characterised by brown, hazy fumes) which irritates the eyes and lungs, leads to the cracking of rubber and extensive damage of plant life. Smog is a combination of smoke and fog. Smog containing high levels of sulphur dioxide is called **reducing smog**. Peroxyacyl nitrate (**PAN**) is a potent eye irritant found in photochemical smog.

Oxides of nitrogen and sulphur entering the atmosphere are converted into nitric acid and sulphuric acid respectively. They combine with hydrochloric acid from HCl emission to generate acidic precipitation known as **acid rain**. Acid rain is now a major pollution problem in some areas. It causes extensive damage to buildings and sculptural materials of marble, limestone, slate, mortar, etc. It is harmful for aquatic plants and animals, and causes soil acidification.

Small solid particles and liquid droplets are collectively called **particulates**. These are present in large amounts in the atmosphere and sometimes pose a serious air-pollution problem. Examples of processes which inject particulate matter into the atmosphere: volcanic eruptions, blowing of soil and dust by wind, formation of fly ash from power plants, smelters and mining operations, and smoke from incomplete combustion processes. Airborne asbestos (a fibrous silicate mineral) and toxic metals like beryllium are carcinogenic. Fine particles (less than 3 microns) are the worst causes of lung damage. Coal miners' **black-lung disease**, and asbestos workers' **pulmonary fibrosis** are associated with the accumulation of such small particles. Very fine particulate matter, which is less than 2.5 microns in size, is called **PM 2.5** and is known to cause diabetes and cardiovascular diseases. Air in Delhi is choking with pollutant PM 2.5. Any kind of combustion, especially of vehicular origin, contains this particle. If PM 2.5 is not regulated it will increase the number of patients suffering from asthma and lung cancer. It brings about lead deposition in the lungs. Particulates accelerate corrosion of metals and cause damage to buildings, sculptures, paints, etc. Particulates in the atmosphere reduce visibility and influence the climate through the formation of clouds, rain and snow.

Burning **CNG** has the highest rates of potentially hazardous carbonyl emissions. Retrofitted CNG car engines emit 30% more methane than original CNG engines. Almost all CNG car engines in India are retrofitted.

Coal pollution kills more than 300,000 people every year. Nitrogen and sulphur oxides emitted by aircrafts, at an altitude of 35,000 ft, combine with other gases in the atmosphere to create harmful pollutants.

Vehicle emission is responsible for 70% of the air pollution in India. Bangalore is called the asthma capital of India. The levels of suspended particulate matter are above permissible limits in Mumbai. **Bhopal gas tragedy** was the greatest industrial disaster in the world that took place at a Union Carbide pesticide plant in the Indian city of Bhopal, Madhya Pradesh. On 3rd December, 1984 (midnight), the plant accidentally released methyl isocyanate (MIC) gas. Within a week about 10,000 people died, 1,000 became blind while more than 1 lakh continued to suffer from various disorders. This was the deadliest man made environmental disaster in history.

On 14 July 2010, chlorine gas leaked from the Sewri industrial area on land owned by the Mumbai Port Trust and approximately 76 people were treated in hospital.

Rice crop yields in Southern India are decreasing as brown clouds are increasingly blocking the sunlight. The brilliant white of the famous **Taj Mahal** is slowly fading to a sickly yellow. The Supreme Court ordered the closure of more than 200 factories to save the Taj Mahal from being polluted by fumes.

There has been a drastic fall in the number of butterflies in the Western Himalayas, famous for their biodiversity. In areas of Himachal Pradesh, and Jammu and Kashmir, the population of 50% of the 288 species has declined more than half in just 10 years.

Over 700 million people in India suffer from high levels of **indoor air pollution** as 75% homes use biomass fuel like wood, crop residue and dung cakes.

Excessive ultraviolet radiation coming from the sun through the **ozone layer** in the upper atmosphere, which is eroded by some air pollutants, may cause skin cancer in wildlife and damage to trees and plants. Ozone in the lower atmosphere may damage lung tissues of animals, and adversely affect plant respiration and photosynthesis.

Water Pollution

Water pollutants include insecticides and herbicides, food processing waste, pollutants from livestock operations, volatile organic compounds (VOCs), heavy metals, chemical waste, disease causing agents, sewage, detergents, oil, sediments and radioactive materials. Beryllium, boron, cadmium, chromium, cyanide, lead, mercury, selenium, silver, sulphide, vanadium and zinc are some of the toxic water pollutants.

Waterborne diseases caused by polluted drinking water are typhoid, amoebiasis, giardiasis, ascariasis, hookworm, hepatitis, encephalitis, gastroenteritis and diarrhoea. Conditions related to water polluted by chemicals are cancer, hormonal problems, and damage to liver, kidney, nervous system and DNA. Water polluted by mercury can lead to Parkinson's disease, Alzheimer's disease, heart disease, etc.

According to a United Nations report released on 22 March 2010 on World Water Day, contaminated and polluted water kills more people than all forms of violence including wars. 80% of urban waste in India ends up in rivers. The **river Ganga** is dying slowly due to unchecked pollution. Samples taken from the river Ganga near Varanasi showed that levels of fecal coliform, a dangerous bacterium that comes from untreated sewage, were some 3,000 per cent higher than what is considered safe for bathing.

Chemical contamination in water can cause declines in frog biodiversity. Persistent organic pollutants (POPs) may cause declines, deformities and death of fish life. Plants and animals may be killed by too much sodium chloride (ordinary salt) in water. Plants may be killed by herbicides in water. Water pollution may disrupt photosynthesis in aquatic plants.

Soil Pollution

Soil pollutants include hydrocarbons, solvents and heavy metals. Soil contamination causes cancer. Lead in soil damages the brain, and mercury leads to kidney damage. It causes headache, nausea, fatigue, eye irritation, skin rashes, and depression of the central nervous system. It may alter plant metabolism and reduce crop yields. It can alter the metabolism of microorganisms. Trees and plants may absorb soil contaminants and pass them up the food chain. This may lead to increased mortality rates and even animal extinction.

Fossil Fuel Pollution

Fossil fuels (oil, gas, coal) are used in vehicles, power-generating plants, and in the manufacture of products like plastics, solvents, detergents, lubricating oils, etc. Fossil fuels contribute to soil contamination and water pollution. When oil is transported by pipelines, an oil leak from the pipeline may occur and pollute the soil, and subsequently the groundwater. When oil is transported by tankers in an ocean, an **oil spill** may occur and pollute ocean water. Transport and power-generating plants are the biggest sources of fossil fuel pollution. Fossil fuel combustion is also a major source of carbon dioxide emissions (air pollution) and perhaps the most important cause of **global warming**.

Other Sources of Pollution

Agriculture (livestock farming) is the largest generator of ammonia emissions resulting in air pollution. Pesticides and fertilizers used in agriculture lead to water and soil pollution.

Plastic bags, plastic sheets, etc. are a major source of pollution. The sale of plastic or polythene bags has been banned in the vicinity of rivers and other water bodies, from 20 January 2011. There is a lot of pollution due to **mining**. The mines of Mahanadi Coal Fields and NTPC release water, containing obnoxious substances like ash, oil, heavy metals, grease, fluorides, phosphorus, ammonia, urea and sulphuric acid, into the **river Nandira** (India). The releases from chlorine plant cause chloride and sodium toxicity to the **river Rushikulya**, the lifeline of southern Orissa. The effluents from Phosphoric Fertilizer Industry, containing sulphuric, nitric and phosphoric acids, are discharged into **river Mahanadi**. Stone mining is linked to diseases like silicosis, tuberculosis, asbestosis, and asthma. Rajasthan is the largest producer of dimensional stones in the country. An aluminium refinery in Orissa continues to pollute the surrounding villages. Red mud is the final waste product from bauxite, an ore of aluminium. Water resources in Jharkhand have been badly contaminated due to extensive coal mining and industrial growth in this region. On 20 February 2010, the Supreme Court directed cancellation of 157 mining leases operating in Rajasthan's eco-sensitive Aravalli Hills, because mining has led to depletion of 90% of forest cover, and drying up of wells that affected agriculture.

Pollution due to **biomedical waste** spreads life-threatening diseases. In April, 2010 a machine from Delhi University containing cobalt-60, a radioactive metal used for radiotherapy in hospitals, ended up in a scrap yard in the city. A scrap yard worker died because of radiation poisoning.

India produces large amounts of **e-waste** from refrigerators, television sets, personal computers, printers and mobile phones. The toxic gases and the large volume of electronic waste increase environmental pollution.

Two merchant vessels, **MSC Chitra and Khalijia-III**, collided off the Mumbai coast on 7 August, 2010, causing an oil spill. Several containers, some of them containing hazardous chemicals, fell into the sea. In September 2010, an unknown ship dumped tons of waste oil into the sea off Goa, creating tar balls, which got deposited on the beaches.

Fireworks are one of the provoking factors for bronchial asthma.

The **distillery sector** is a major polluting industry in India. It generates large amounts of dark brown coloured wastewater, called **spent wash**, which contains organic pollutants. When discharged in water bodies, this spent wash causes depletion of dissolved oxygen in water and adversely affects aquatic life. When discharged on land, it pollutes groundwater and drinking water. Use of this distillery waste water for irrigation of crops causes soil pollution.

The Most Polluted Places in India

Vapi (Gujarat) and Sukinda (Orissa) are among the top ten most polluted places in the world. The pollutants are chemicals and heavy metals in Vapi and chromium in Sukinda. Fifty one Indian cities have extremely high air pollution with Patna, Lucknow, Raipur, Faridabad and Ahmedabad topping the list. The worst five Indian power companies (in terms of total emission of carbon dioxide) are NTPC, Maharashtra State Power Gen Co., Gujarat Urja Vikas Nigam, Uttar Pradesh Rajya Vidyut, and Andhra Pradesh Power Gen Corp.

Fukushima Daiichi Nuclear Disaster

Following the Tohoku earthquake and tsunami on 11 March, 2011 the Fukushima Daiichi (Japan) nuclear disaster was a series of equipment failures, nuclear meltdowns and releases of radioactive materials at the Fukushima Nuclear Power Plant. The plant comprises six separate boiling water reactors maintained by the Tokyo Electric Power Company (TEPCO). The entire plant was flooded, all power for cooling was lost and reactors started to overheat, owing to natural decay of the fission products created before shutdown. This was the worst nuclear accident in 25 years, which displaced 50,000 households after radiation leaked into the air, soil and sea. The primary releases of radioactive nuclides were those of **Iodine-131** and **Cesium-137**. **Strontium** and **Plutonium** were also found. Iodine-131 has a half-life of 8 days while Cesium-137 has a half-life of over 30 years.

Fear of radiation from Japan prompted a global rush for potassium iodide pills. This included the United States, Canada, Russia, Korea, China, Malaysia and Finland. Iodine-131 is easily absorbed by the thyroid. This can lead to thyroid cancer. Potassium iodide tablets prevent Iodine-131 absorption by saturating the thyroid with non-radioactive iodine. Cesium-137 can cause acute radiation sickness, and increases the risk for cancer. Prussian blue helps the body excrete Cesium-137.

Saviours of Biodiversity

Environmental pollution is causing a lot of distress not only to humans but also to animals, driving many animal species to endangerment and even extinction. Methods are being devised to save this precious biodiversity.

A.2.15 GREEN CHEMISTRY

Green Chemistry is a specific type of **prevention of pollution**. It involves the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. It has been applied to a wide range of industrial and consumer goods, including paints, dyes, fertilizers, pesticides, plastics, medicines, electronics, dry cleaning, energy generation and water purification.

Hazard is simply another property of a chemical substance. As properties of chemicals are because of their specific molecular structure, they can be modified by changing that structure. Various types of hazards that can be handled by Green Chemistry include physical hazards (being explosive or inflammable), toxicity (being carcinogenic or cancer causing, or lethal) or global hazards (climate change or stratospheric ozone depletion). Like a substance can be designed to have a low melting point or green colour, it can also be designed to be non-toxic.

Tools used in Green Chemistry

By choosing an alternate synthetic design, we focus not on the ultimate molecule but on the synthetic pathway used to create it. Modification of the synthesis can lead to the same final product, yet reduce or eliminate toxic starting materials, by-products and wastes. The following tools can be used to modify a synthesis:

1. Alternative Feedstocks (Starting Materials) The selection of a feedstock, i.e., the starting material used for the manufacture of a product, determines what hazards will be faced while handling this substance. A feedstock must be evaluated to determine whether it possesses chronic toxicity, carcinogenicity, ecotoxicity, etc. Currently, most of the organic chemicals are made from petroleum feedstocks. Petroleum undergoes oxidation during conversion to useful organic chemicals. This oxidation step is one of the most environmentally polluting steps of chemical synthesis. It has contributed to the risk to human health and the environment, mainly through the use of heavy metals, like chromium, as oxidising agents. It is, therefore, important to reduce the use of petroleum-based products. **Agricultural** and **biological feedstocks** are excellent alternative starting materials. They are already highly oxygenated. Therefore, their use eliminates the need for the polluting oxygenation step. A raw material or feedstock should be **renewable** rather than depleting. Petroleum and other fossil-fuel based feedstocks are depleting and feedstocks based on biomass and agricultural wastes are renewable.

At present a host of agricultural products like soy, potatoes, corn and molasses are being transformed through a variety of processes into consumer products like textiles, nylon etc.

2. Alternative Reagents Alternative reagents are being increasingly used to carry out synthesis. For example, heavy metals, used in petroleum oxidation processes, are quite toxic and carcinogenic. They are being replaced by **light** to carry out the required transformation.

3. Alternative Solvents Many solvents commonly used in synthesis are volatile organic compounds (VOCs) that cause smog when released in air. Individuals with respiratory problems suffer great distress because of this environmental effect.

Solvents like methylene chloride, chloroform, carbon tetrachloride, benzene, etc. have been identified as suspected human carcinogens.

The uses of chlorofluorocarbons (CFCs) range from cleaning solvent, propellant, blowing agent for moulded plastic foams, to refrigeration. CFCs have very low direct toxicity to humans and wildlife, and are both non-flammable and non-explosive. However, CFCs are known culprits of ozone layer depletion.

Some of the alternatives to these organic solvents include the use of supercritical or dense phase fluids, such as **supercritical carbon dioxide**. This system is not harmful from human health and environmental point of view.

Supercritical fluids are obtained by subjecting small molecules, like carbon dioxide, to the appropriate temperature and pressure to attain the critical point at which the molecules possess the character of a fluid which is a cross between a liquid and a gas. The properties of this fluid (solvent) can be adjusted by adjusting the parameters of temperature and pressure. Supercritical solvent systems are now replacing a variety of other traditional organic solvents.

Now methods are being developed where the reagents and feedstocks serve as the solvent as well. In some cases the reagents and feedstocks are made to react in the molten state to ensure proper mixing and optimal reaction conditions, or on solid surfaces such as specialised clays. Thus, ways are being designed to carry out reactions in **solventless systems.**

If a solvent is essential for a particular synthesis, then the most innocuous one must be selected. Water is the safest solvent possible. A major problem with many solvents in relation to human health and the environment is their ability to volatilise. The use of immobilised solvents may serve as a solution.

Immobilisation can be done by binding the solvent molecule to a solid support (polymer), so that it becomes non-volatile. Some polymers are being developed which have solvent properties and are not hazardous.

4. Alternative Product (Target Molecule) While designing safer chemicals (target molecules), the object is to maximise the functional benefits of a molecule and minimise or eliminate its toxicity or other hazards. This is done by identifying the part or parts of the molecule that produce toxic effects, and also those that are responsible for its desired function. The part related to the toxic effect can be avoided or suitably changed to reduce or eliminate the toxic effect.

Another way to reduce hazardous effects of a substance is to minimize its **bioavailability**. If a toxic substance is not able to reach its target organ (e.g. heart, lungs, liver), where it can manifest its toxicity, then it is rendered innocuous for all purposes. By changing the physical and chemical properties of a molecule, like solubility in water and polarity, the absorption of molecules through biological membranes and tissues can be made difficult or impossible. Elimination of absorption and bioavailability leads to reduction in toxicity.

5. Green Analytical Chemistry The detection, measurement and monitoring of chemicals in the environment is done through Analytical Chemistry. Instead of determining environmental problems after they occur, Green Chemistry seeks to prevent the formation of toxic substances. Even minute amounts of toxic substances are detected with the help of sensors and process controls are adjusted to minimise or stop its formation.

6. Alternative Catalysts Catalysis has increased the level of efficiency of chemical synthesis, and has also brought about environmental benefits. Use of new catalysts has eliminated the need for large quantities of reagents that would have been otherwise required to carry out those syntheses. Such large amounts of regents would have increased the bulk of the waste stream.

7. Minimal Energy Requirements Energy requirements of a synthetic procedure should be minimised because energy generation and consumption bring about a major environmental effect. The advantage of using a **catalyst** is that it lowers the energy of activation needed to accomplish a reaction, and therefore, minimises the thermal energy required for the transformation.

Microwave energy is now being utilised in order to effect chemical reactions rapidly, and generally in the solid state. This eliminates prolonged heating necessary to carry out a reaction. Through the use of **ultrasonic energy**, the conditions of the reactants are considerably changed to promote a chemical transformation.

8. Alternative Methodology Unnecessary use of blocking groups, protecting groups, additional functional groups should be avoided, because this requires use of materials (often hazardous) to make the substance and generates a waste in the regeneration of the original substance.

Some methods make use of toxic chemicals such as cyanide or chlorine. In addition, these methods at times generate large quantities of hazardous wastes. For example, the pulp and paper industry uses chlorine compounds in processes that generate toxic chlorinated organic waste. Green chemists have developed a new technology that converts wood pulp into paper using oxygen, water, and polyoxometalate salts. Water and carbon dioxide are the only by-products.

Substances used in a chemical process should be chosen so as to minimise the chances of chemical accidents, including explosions and fires.

9. Designing for Biodegradability Chemical products should be designed so that after their function is over they do not persist in the environment and do not accumulate in plant or animal systems, but break down into innocuous degradation products.

Plastics are known for their durability and long life. That is why they cause environmental concerns in oceans and other aquatic media. Pesticides tend to bioaccumulate in many plant and animal species, thereby causing damage to the species itself, or, to humans if consumed. These products should be designed so that they do not remain in their initial state in the environment after their useful life is over. Their degradation products also should not be toxic or hazardous.

10. Green Chemistry Evaluation Whether dealing with a reagent, solvent, product, starting material or the process itself, the following essential characteristics need to be known to conduct a Green Chemistry evaluation:

(i) Toxicity to humans
(ii) Toxicity to wildlife
(iii) Effects on the local environment
(iv) Global environmental effects

Examples of Green Chemistry

1. Polysaccharide Polymers Polysaccharides are biological feedstocks, which are **renewable**, in contrast to the feedstocks obtained from petroleum and other fossil fuels. They have no significant toxic effects on human health and the environment. Their accident potential is negligible. Above all, they are **biodegradable** in the ecosystem after their useful life is over. This is the greatest advantage over most polymers, which tend to persist in the environment.

2. Chemical Products from Biomass The waste biomass includes resources like municipal solid waste, sewage sludge, manure and agricultural residues. Technologies have been developed to convert this waste biomass into animal feed, fuels and industrial chemicals.

Chemicals may be produced economically from waste biomass. These wastes, otherwise, contribute to land or air pollution and incur a disposal cost. Production of chemicals from biomass leads to conservation of non-renewable resources such as petroleum and natural gas. Moreover, oxygenated fuels obtained from biomass do not add carbon dioxide to the environment, and therefore, do not facilitate global warming.

3. Reduced Risk Insecticides Spinosad, a reduced risk insecticide, is manufactured by fermenting a naturally occurring soil organism. It does not bioaccumulate, volatilise, or persist in the environment, and does not harm 70–90% of beneficial insects. It has low toxicity to mammals and birds and is mildly toxic to aquatic organisms, but is toxic to bees until it dries.

4. Safer Solvents Ethyl lactate is a cleaning solvent made from cornstarch and soybean oil. It biodegrades to carbon dioxide and water and has no known harmful effects on humans, wildlife or the environment.

Green Chemistry addresses the problem of hazard at the molecular level, and can be applied to all kinds of environmental issues.

A.2.16 COMBINATORIAL CHEMISTRY

Combinatorial Chemistry (or **CombiChem**) is the method of synthesising many different substances simultaneously at a very quick rate. This method is much faster than the time consuming and labour intensive methods of traditional chemistry. CombiChem is primarily used to prepare new drugs. It is also being applied to other fields such as semiconductors, superconductors, catalysts and polymers. A large number of compounds can be synthesised by combining sets of building blocks and each new compound has a composition slightly different from the previous one. Whereas a traditional chemist can synthesise 100–200 compounds in a year, the combinatorial robotic system can produce thousands or millions of compounds per year.

A.2.17 COMPUTATIONAL CHEMISTRY

Computational Chemistry is the branch of Chemistry that makes use of principles of **Computer Science** to solve chemical problems. It uses computer programs, based on the results of **Theoretical**

Chemistry, to determine the structures and properties of compounds. It is used extensively in **drug designing**.

A.2.18 PREBIOTIC CHEMISTRY

Prebiotic Chemistry deals with the spontaneous chemical reactions which may have led to the formation of biomolecules and life on earth. It includes abiotic reaction pathways leading from inorganic substances to organic substances to biomolecules or bio-like molecules.

A.2.19 SUPRAMOLECULAR CHEMISTRY

Supramolecular Chemistry is the area of Chemistry beyond the molecules. It deals with the chemical systems made up of a discrete number of assembled molecular subunits. In contrast to traditional chemistry, which focuses on covalent bonds, supramolecular chemistry examines the weaker and reversible interactions between molecules like hydrogen bonding, metal coordination, hydrophobic forces, van der Waals forces, pi-pi interactions, and electrostatic effects. The study of such non-covalent interactions is important to understand biological processes.

Applications of Supramolecular Chemistry

- Large structures can be easily prepared using bottom-up synthesis as they are made up of small molecules requiring fewer steps to synthesise. Most of the bottom-up approaches to **nanotechnology** are based on supramolecular chemistry.
- It is used in the design and understanding of **catalysts**.
- It is used in the development of new **pharmaceutical therapies**.
- It has application in **Green Chemistry** where reactions are made to proceed in the solid state directed by non-covalent bonding. This reduces the need for solvents during the production of chemicals.
- It has been applied to develop high-tech sensors, processes to treat radioactive waste, and contrast agents for **CAT scans**.

A.2.20 BIOCATALYSIS

Biocatalysis involves the use of natural substances, like **enzymes** or cells, to catalyse chemical reactions. An enzyme is simply a protein catalyst. Enzymes help in digestion of food, production of vital nutrients, etc. Enzymes are also used to improve the performance of detergents, make beer and wine, process food, etc.

Biocatalysis can be used to replace many traditional chemical catalysts, including catalysts that are toxic or contain chemical residues that pollute the environment. One of the most important advantages of biocatalysis is **high selectivity**, manifested as stereo-selectivity (often used for the synthesis of drugs in which only one stereoisomer possesses the desired biological activity), positional selectivity (allowing reaction to take place at a particular site in a molecule), and functional group selectivity (allowing a particular functional group to participate in the reaction). Such selectivity results in higher yields, fewer side reactions, elimination of protection and de-protection steps, purer products, easier recovery and separation and reduced environmental waste. Biocatalysed reactions take place under mild operational conditions, avoiding extremes of pH, temperature and pressure. Biocatalysts are **biodegradable** and are produced from **renewable resources**. Thus, biocatalytic processes are **“greener”**, more sustainable, and involve less pollution and cost. Biocatalysts can be used to catalyse chemical reactions in industrial processes, including the production of drugs, flavours, fragrances, polymers—chemicals that impact almost every facet of our life.

A.2.21 BIOMATERIALS

Biomaterials are used for improving the quality of life. Their range of applications is vast and includes things like joint and limb replacements, artificial arteries and skin, contact lenses, and dentures.

Biomedical materials are divided into three main types depending on tissue response: **inert materials** induce no or minimal tissue response; **active materials** encourage bonding to surrounding tissue (e.g., new bone growth being stimulated); **degradable or resorbable materials** are incorporated into the surrounding tissue, and may dissolve completely over a period of time. Metals are inert, ceramics may be inert, active or resorbable, and polymers may be inert or resorbable.

Examples of biomaterials:

1. **Metals:** Titanium, Ti6Al4V, Co-Cr alloys, 316L stainless steel
2. **Ceramics:** Carbon, alumina, zirconia, hydroxyapatite
3. **Polymers**: Polyurethane, ultra high molecular weight polyethylene

The main requirement of a biomaterial is that is should not induce any adverse reaction when placed into service. Metallic biomaterials are used for bearing load and must have sufficient strength to endure the pressures of activities like walking, chewing, etc. Ceramic biomaterials are hard and wear resistant. They are used as articulating surfaces in joints and teeth as well as bone bonding surfaces in implants. Polymers are used for their flexibility and stability, and also as low friction articulating surfaces.

Applications of Biomaterials

1. Orthopedic Applications Metallic biomaterials are used for load bearing as in pins, plates and femoral stems. Ceramics such as alumina and zirconia are used for wear applications in joint replacements. Hydroxyapatite is used for bone bonding applications. Polymers like ultra high molecular weight polyethylene are used as articulating surfaces in joint replacements. Alumina is used to replace large sections of bone which have to be removed due to disease.

2. Dental Applications Metallic biomaterials are used as pins for anchoring tooth implants and as parts of orthodontic devices. Ceramics are used as tooth implants. Hydroxyapatite is used for coatings on metallic pins and to fill large bone voids. Polymers are used in orthodontic devices like plates and dentures.

3. Cardiovascular Applications Carbon is used in heart valves and polyurethanes for pace maker leads.

4. Cosmetic Surgery Materials such as silicones have been used in cosmetic surgery.

A.2.22 BIOMIMETICS

Biomimetics, also known as **Biomimicry** or **Bionics**, is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. It refers to human made processes, materials, devices or systems that imitate nature. There are three areas in biology based on which technological solutions can be modeled:

- Replicating natural methods of production of chemical compounds by plants and animals, e.g., Chinese trying to make artificial silk
- Mimicking mechanisms found in nature, such as spiny hooks on plant seeds and fruits inspiring velcro
- Imitating organisational methods of organisms like ants, bees and micro-organisms

Some fascinating examples of biomimicry:

- Birds inspiring aircraft and wing design
- Seashells inspiring better ceramics
- Self-healing properties of biological systems inspiring the production of polymers capable of mending cracks
- Mimicking mechanisms of photosynthesis and chemical energy conversion to make cheaper solar cells
- 'Gecko tape' has been inspired by the lizard's ability to climb up walls and walk along ceilings

A new **high fuel efficiency** concept vehicle is being developed, based on the body shape of a boxfish (a cube shaped fish). This car will offer 20% lower fuel consumption and up to 80% lower nitrogen oxide emissions. Biomimetics will help us develop technologies that reduce our impact on the environment and also improve our quality of life.

A.2.23 BIOPOLYMERS

Biodegradable polymers are known as biopolymers. Renewable (based on agricultural plant or animal products) or synthetic starting materials may be used to produce biopolymers. There are four types of biopolymers based on:

- Starch
- Cellulose
- Sugar
- Synthetic materials

A polymer can be built up from a monomer by the process of chemical **polymerisation**, or a naturally occurring polymer can be chemically modified to give it the desired properties.

Every biopolymer has its own material-specific properties. **Bioplastics** are used in pesticide soil pins, for packaging in-flight catering products and for packaging dairy products.

Thermoplastic starch is not suitable for packaging liquids but has good oxygen barrier properties. Starch is a natural polymer, which can be obtained from potatoes, maize, wheat, etc.

Polylactides (lactic acid polymers) are made from lactic acid, which itself is made from lactose (or milk sugar). Polylactides are water resistant and decompose harmlessly in the human body. They are, therefore, used for medical applications like surgical implants which do not require operative removal. Polyhydroxy butyrate is made from sucrose or starch by a process of bacterial fermentation.

Cellulose is used for making packaging material such as cellophane, which is transparent and has good folding properties.

Synthetic compounds obtained from petroleum can also serve as starting materials for biodegradable polymers.

Biopolymers are available on a sustainable basis. They have several economic and environmental advantages, and are an asset to waste processing. Replacing polyethylene used in coated papers by a biopolymer can help eliminate plastic scraps occurring in compost.

A.2.24 BIOASSEMBLIES

The membranes around body cells and around small structures inside the cells are composed of complex lipids. Complex lipids can be classified into two groups:

1. **Phospholipids** These contain an alcohol, two fatty acids and a phosphate group.
2. **Glycolipids** These contain an alcohol, a fatty acid and a carbohydrate.

The cell membranes separate cells from the external environment and provide selective transport for nutrients and waste products into and out of cells. These membranes are made of lipid bilayers.

Cholesterol is also an important component of membranes. The unsaturated fatty acids present in the lipid bilayer provide a liquid-like character to the membranes. This property of membrane fluidity is of extreme importance because many products of biochemical processes in the body must cross the membrane and the liquid nature of the lipid bilayer allows such transport.

Increasing knowledge about the composition and dynamics of cell membranes in combination with development of methods for forming synthetic membranes have enabled a new approach to the study of **biomembranes**, the construction of cell-like bioassemblies. This will enable the design of biosynthetic hybrid devices that could revolutionise biodetection, therapeutics and bioenergy.

A.2.25 RENEWABLE ENERGY RESOURCES

Solar energy, wind energy, hydel energy, geothermal energy and the energy from biomass constitute the renewable energy resources.

Solar Energy

Plants use solar energy (light) for photosynthesis. **Solar panels** are now being used to absorb solar energy for heating water for domestic and industrial uses; **solar cookers** are used for cooking; and **solar photovoltaic** (**SPV**) **cells** have been developed that convert solar energy into electricity to be used in homes, streets and even in villages.

Solar power plants (photovoltaic plants) have already been established in Tamilnadu, Karnataka, Punjab, Delhi, Gujarat, Maharashtra and Rajasthan for harnessing solar energy.

Wind Energy

Wind energy is also a clean and renewable energy. It does not produce any pollutants and, therefore, has great potential for the future. It is being used for grinding, water pumping (**windmills**), or to generate electricity.

Wind energy is the fastest growing renewable energy sector in our country (with Tamil Nadu, Maharashtra, Gujarat, Karnataka and Rajasthan leading the list) with a cumulative development of over 13,000 MW wind power generation.

Hydel Energy

Hydel energy involves the use of energy of running or falling water. It is used to run the turbines that convert kinetic energy of water into electrical energy. **Hydroelectric power** is a very clean energy source with no environmental pollution from greenhouse gases (carbon dioxide, nitrous oxide, etc.) and no expenses for fuel.

Geothermal Energy

Geothermal energy refers to the heat energy generated and stored in the earth. The earth's core is very hot and this is demonstrated by the eruption of **volcanoes** in several parts of the world. This hot core, volcanic activity and the decay of radioactive mineral deposits of the earth are primary sources of this geothermal energy.

United States of America is the leading producer of electricity from this energy with an installed capacity of 3086 MW (2010) followed by Phillipines, Indonesia, Mexico, and Italy. There are more than 20 countries in the world harvesting geothermal energy for electricity generation.

There are more than 350 hot spring sites in India, mainly in the North Western Himalayas and the Western Coast. The Puga valley in the Ladakh region (J&K) has the most promising geothermal field and an experimental power generator is already in operation in this region. Hot water tanks for bathing and cooking have been in use for thousands of years at the famous pilgrimage centre of Shri Badrinath and Yamnotri (Uttarakhand). There are a number of **hot water springs** in Manikaran (Himachal Pradesh).

The geothermal energy is considered clean, cost effective and sustainable. Therefore, it has great potential as an unconventional energy resource for future.

Biomass Energy

Biomass energy is a renewable energy resource as it is obtained from plant material and animal waste that can be obtained continuously. The primary sources of biomass are the plants, animal waste, biodegradable municipal waste, waste wood, paper and sugar industries, agricultural waste, etc. Biomass can be used directly as an energy source for heating, cooking, etc., or can be converted into other forms for use, such as **biogas**, **biofuel**, **syngas**, etc.

Animal waste (gobar) is used for producing biogas for domestic or community use. Biofuels are produced from plant materials to produce fuels (bioethanol or biodiesel) for vehicles to reduce our dependence on fossil fuels and also to reduce atmospheric pollution.

Syngas is produced from biodegradable municipal solid waste through the processes of incineration and gasification. There is a need to reduce the wastage of energy by improving our energy output systems—electricity generating systems, our transport systems, our buildings, etc. For example, the incandescent light bulb wastes 95% electrical energy as heat that can be saved by using more efficient CFL tubes. Likewise our present motor vehicles waste 86–90% of its energy (fuel) as heat. This wasted energy is the cause of our **global warming** and the resulting **climate change**.

> The village **Ralegaon Siddhi** (home village of the social worker and activist **Anna Hazare**) has become famous for harnessing renewable (non-conventional) energy resources, such as **solar energy**, **wind energy** and **biogas**. All the streets are lit by solar lights, each with a separate panel. There is a windmill for pumping water and there are large and small biogas plants for community and domestic use.

A.2.26 STEPS TO REDUCE POLLUTION

Most countries have framed rules and regulations to control pollution at their level.

- The Government of India constituted the Central Pollution Control Board (CPCB) in 1974. In 1986, the government enacted a comprehensive law—the **Environment Protection Act** (**EPA**), 1986, with the objective to provide protection and improvement of the environment. The act specifies that the state shall protect and improve the environment and shall also safeguard the forests and wildlife. The act (EPA) is applicable to the whole of India, including Jammu & Kashmir. The act provides for a fine upto one lakh and/or imprisonment upto 5 years for any person or company found guilty of environmental pollution.
- On 19 October 2010, India launched a **Green Court** to make polluters pay damages.
- An agreement was made on 13 January, 2010, between India and the World Bank to advance **India's green growth agenda**. The Bank will give support for biodiversity conservation and pollution control.
- Indian scientists aim to build an advanced **coal-fired power plant**. This technology would produce much less pollution as compared to the current thermal power plants.
- **National Clean Energy Fund (NCEF)** has been allocated in the Union Budget (2010–11) for funding research and innovative projects in clean energy technology. The **"Mission Clean Ganga 2020"** under the National Ganga River Basin Authority **(NGRBA)**, with the objective that no untreated municipal sewage or industrial waste will be discharged into the Ganga river, has already been initiated.
- The atomic trade pact with US and an atomic energy pact with France will help India fight global warming with clean **nuclear energy**. Use of nuclear energy will reduce the amount of green house gas emissions.

At the international level, there have been a number of conventions, protocols, and treaties to control/regulate atmospheric pollution. Some of these are listed below:

- Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) or Washington Convention (1975)
- Vienna Convention for the Protection of Ozone Layer (1988)
- Sulphur Emissions Reduction Protocol (1987)
- Antarctic Environmental Protocol (1998)
- Basal Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1992)
- ESPOO convention (1997): It is an international agreement that regulates the assessment of environmental impact in the case of projects which have transboundary effects.
- Convention on Biological Diversity or Biodiversity Treaty (1993)

- Montreal Protocol (Protocol on Substances that Deplete the Ozone Layer) (1989): It has been proposed (2011) to phase down the production and consumption of hydrofluorocarbons (HFCs) under the Montreal Protocol.
- Nitrogen Oxide Protocol (1991) to control the emission of nitrogen oxide
- Convention on Nuclear Safety (1996): It is an international treaty to ensure maintenance of high level safety for the land-based nuclear power plants.
- Kyoto Protocol (2005): It is an update of the 1994 United Nations Framework Convention on Climate Change aimed at fighting global warming.
- Rotterdam Convention (2004): It is a multilateral United Nations treaty to ensure prior informed procedure for certain hazardous chemicals and pesticides in international trade.
- Stockholm Convention on Persistent Organic Pollutants (2004): It is an international environmental treaty aimed at elimination or restriction of the production and use of persistent organic pollutants (POPs) as they persist in the environment and bio-accumulate through food webs posing serious threat to human health. The substances listed as POPs are aldrin, chlordane, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, PCBs (polychlorinated biphenyls), DDT, dioxins (polychlorinated dibenzo-p-dioxins), polychlorinated dibenzofurans.
- POP Air Pollution Protocol (2003): (Protocol to the 1979 Convention on Long Range Transboundary Air Pollution by Persistent Organic Pollutants.) It is an international treaty to control emissions of persistent organic pollutants (POPs) to reduce their transboundary fluxes.
- United Nations Framework Convention on Climate Change (1994). The UNFCCC is a section of the United Nations, concerned with operations of the convention, and has offices in Haus Carstanjen, Bonn, Germany. After it came into force in 1994, it holds annual conferences, called Conferences of the Parties (COP). The first conference was held in March, 1995, in Berlin, Germany, and the latest (17th) was held in Durban, South Africa from November 28 to December 9, 2011. Most countries agreed to legally binding reductions in greenhouse gas emissions of an average of 6 to 8% below 1990 levels between 2008–2012.

International Year of Biodiversity (2010)

The International Year of Biodiversity (IYB) was a year-long celebration of biological diversity and its value for life on earth, taking place around the world in **2010**. Coinciding with the date of the 2010 Biodiversity Target, the year was declared by the 61st session of the United Nations General Assembly in 2006. The Secretariat of the Convention on Biological Diversity (CBD), based in Montreal, Canada, was coordinating the International Year of Biodiversity campaign.

The main goals of the International Year of Biodiversity were to:

- Raise awareness of threats to biodiversity and the importance of conserving biodiversity.
- Raise awareness of the accomplishments to save biodiversity that have already been realised.
- Promote innovative solutions to reduce the threats to biodiversity.
- Encourage immediate steps to halt biodiversity loss.

Slogan: *Biodiversity is life.*
Biodiversity is our life.

GLOSSARY

Acid rain: The precipitation of dilute solutions of strong mineral acids, formed by the mixing in the atmosphere of various industrial pollutants, primarily sulphur dioxide and nitrogen oxides, with naturally occurring oxygen and water vapour.

Aerosol: Suspension of small liquid or solid particles in gas.

Air pollution: Toxic or radioactive gases or particulate matter introduced into the atmosphere, usually as a result of human activity.

Alternative energy: Energy that is not popularly used and is usually environmentally sound, such as solar or wind energy (as opposed to fossil fuels).

Alternative fibres: Fibres produced from non-wood sources for use in paper making.

Alternative fuels: Transportation fuels other than gasoline or diesel. They include natural gas, methanol and electricity.

Antabuse: Sometimes given as a treatment for chronic alcoholism.

Ash: Incombustible residue left over after incineration or other thermal processes.

Asthma: A condition marked by labored breathing, constriction of the chest, coughing and gasping usually brought on by allergies.

Atropine: Used to dilate the pupil of the eye to facilitate examination of its interior.

Bioaccumulation: The accumulation of a chemical in tissues of an organism to levels greater than in the surrounding medium. Accumulation may take place by breathing, swallowing or dermal contact.

Biocatalysis: Involves the use of natural substances, like enzymes, to catalyse chemical reactions. Biocatalysts are biodegradable and are produced from renewable resources.

Biodegradable: Waste material composed primarily of naturally-occurring constituent parts, able to be broken down and absorbed into the ecosystem. Wood, for example, is biodegradable, while plastics are not.

Biodiversity: A large number and wide range of species of animals, plants, fungi, and microorganisms. Ecologically, wide biodiversity is conducive to the development of all species.

Biofuel: Any liquid, solid or gas fuel refined in whole or in part from sustainable biological materials, usually plants. Some biofuels, like ethanol, are refined from food plants such as corn, but technologies are being developed to use non-food plants and crop residue from food plants.

Biomass: Plant materials and animal waste used as fuel.

Biomass energy: A renewable energy resource obtained from plant material and animal waste.

Biomimetics: The application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. It refers to human made processes, materials, devices, or systems that imitate nature.

Biosphere: The part of the earth and its atmosphere in which living organisms exist or that is capable of supporting life.

Birth defects: Unhealthy defects found in newborns, often caused by the mother's exposure to environmental hazards or the intake of drugs or alcohol during pregnancy.

Blood lead levels: The amount of lead in the blood. Exposure to lead can cause brain damage, especially in children.

Carbon dioxide: A naturally occurring greenhouse gas in the atmosphere, concentrations of which have increased (from 280 parts per million in pre-industrial times to over 350 parts per million today) as a result of burning of coal, oil, natural gas and organic matter (e.g., wood and crop wastes).

Carcinogens: Substances that cause cancer, such as tar.

Chlorofluorocarbons (CFCs): Stable, artificially-created chemical compounds containing carbon, chlorine, fluorine and sometimes hydrogen. Chlorofluorocarbons, used primarily to facilitate cooling in refrigerators and air conditioners, have been found to damage the stratospheric ozone layer which protects the earth and its inhabitants from excessive ultraviolet radiation.

Clean fuels: Fuels which have lower emissions than conventional gasoline and diesel.

Combinatorial Chemistry (or **CombiChem**): The method of synthesising many different substances simultaneously at a very quick rate. It is primarily used to prepare new drugs.

Compost: Process whereby organic wastes, including food wastes, paper, and yard wastes, decompose naturally, resulting in a product rich in minerals and ideal for gardening and farming as a soil conditioner, resurfacing material, or landfill cover.

Computational Chemistry: The branch of Chemistry that makes use of principles of Computer Science to solve chemical problems. It is used extensively in drug designing.

Corrosive poisons: Toxic substances which destroy tissues and enzymes, e.g., strong acids and alkalies, and many oxidants.

DDT: A common pesticide which attacks the central nervous system of insects. It is fairly stable and persists in the environment.

Emissions cap: A limit on the amount of greenhouse gases that a company or country can legally emit.

Energy conservation: Using energy efficiently or prudently; saving energy.

Essential amino acids: Amino acids which cannot be synthesised by humans and other mammals. It is essential to include them in the diet.

Essential fatty acids: Fatty acids needed in the human body that must be obtained from dietary sources because they cannot be synthesised within the body, in adequate amounts, from other substances.

Ethylenediaminetetraacetic acid (EDTA): An effective agent used to remove lead from the human body.

E-waste: The waste from refrigerators, television sets, personal computers, printers, and mobile phones. The toxic gases and the large volume of electronic waste increase environmental pollution.

Feedstock: The starting material used for the manufacture of a product. Petroleum and other fossil-fuel based feedstocks are depleting, and feedstocks based on biomass and agricultural wastes are renewable.

Fossil fuel: A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilised) plants and animals.

Geothermal energy: Refers to the heat energy generated and stored in the earth.

Global warming: Increase in the average temperature of the earth's surface.

Green Chemistry: Chemistry for the environment, a fundamental new philosophy of thinking that can help chemists in research and production to develop more eco-friendly and efficient products and processes. Green chemistry is the attempt to prevent pollution, to reduce or eliminate the use and generation of hazardous substances and to design chemical products and processes to reduce the harm they cause to ecosystems.

Green design: A design, usually architectural, conforming to environmentally sound principles of building, material and energy use. A green building, for example, might make use of solar panels, skylights, and recycled building materials.

Greenhouse: A building made with translucent (light transparent, usually glass or fiberglass) walls conducive to plant growth.

Greenhouse effect: The process that raises the temperature of air in the lower atmosphere due to heat trapped by greenhouse gases, such as carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and ozone.

Hallucinogens: Chemicals which produce temporary changes in perception, thought and mood.

Haze: An atmospheric condition marked by a slight reduction in atmospheric visibility, resulting from the formation of photochemical smog, radiation of heat from the ground surface on hot days, or the development of a thin mist.

High-density lipoproteins (HDL): They collect excess cholesterol from body tissues and transport it back to the liver for degradation and excretion from the body.

Household hazards: Dangerous substances or conditions in human dwellings.

Hydel energy: Involves the use of energy of running or falling water. It is used to run the turbines that convert kinetic energy of water into electrical energy.

Hydrofluorocarbons: Used as solvents and cleaners in the semiconductor industry, among others; experts say that they possess global warming potentials that are thousands of times greater than carbon dioxide.

Hydropower: Energy or power produced by moving water.

Immobilised solvents: Obtained by binding the solvent molecule to a solid support (polymer).

Immunoglobulins: The basic molecules of the immune system. They are produced by an organism as a protective response to the invasion of microorganisms or foreign molecules.

Lactose intolerance: A condition in which people lack the enzyme lactase and are not able to digest milk.

Landfill: Disposal area where garbage is piled up and eventually covered with dirt and topsoil.

Low-density lipoproteins (LDL): They transports cholesterol synthesised in the liver to cells throughout the body.

Low-emission vehicles: Vehicles which emit little air pollution compared to conventional internal combustion engines.

Metabolic poisons: Toxic substances which cause illness or death by interfering with a vital biochemical mechanism.

Methyl isocyanate (MIC): The raw material for the production of carbamate pesticide. Workers exposed to MIC suffer from chest tightness and breathing troubles.

Mutagens: Chemicals that can change the genes and chromosomes (hereditary pattern) to cause abnormalities in the offspring.

Neurotoxins: Metabolic poisons which limit their action to the nervous system. These include poisons such as strychnine and curare. They act at the point where two nerve fibres come together.

Neurotransmitters: Chemicals located and released in the brain to allow an impulse from one nerve cell to pass to another nerve cell. Nerve cells do not directly touch each other. They communicate messages by secreting neurotransmitters. Some common examples are acetylcholine, norepinephrine, dopamine and serotonin.

Nitrogen oxides: Harmful gases (which contribute to acid rain and global warming) emitted as a byproduct of fossil fuel combustion.

Nuclear energy: Energy or power produced by nuclear reactions (fusion or fission).

Nuclear reactor: An apparatus in which nuclear fission may be initiated, maintained, and controlled to produce energy, conduct research, or produce fissile material for nuclear explosives.

Nuclear tests: Government tests carried out to supply information required for the design and improvement of nuclear weapons, and to study the phenomena and effects associated with nuclear explosions.

Oil spills: The harmful release of oil into the environment, usually in the water, sometimes killing area flora and fauna. Oil spills are very difficult to clean up.

Ozone: A naturally occurring, highly reactive gas comprising triatomic oxygen formed by recombination of oxygen in the presence of ultraviolet radiation. This naturally occurring gas builds up in the lower atmosphere as smog pollution, while in the upper atmosphere it forms a protective layer which shields the earth and its inhabitants from excessive exposure to damaging ultraviolet radiation.

Ozone depletion: The reduction of the protective layer of ozone in the upper atmosphere by chemical pollution.

Ozone hole: A hole or gap in the protective layer of ozone in the upper atmosphere.

Particulate pollution: Pollution made up of small liquid or solid particles suspended in the atmosphere or water supply.

Peroxyacetyl nitrate (PAN): Product of photochemical smog which causes irritation of the eyes and the respiratory tract.

Pesticides: Chemical agents used to destroy pests.

Pheromones: Secreted or excreted chemicals that trigger a social response in members of the same species. Most insects and some vertebrates and plants communicate by using pheromones.

PM10: Particulate matter less than 10 microns in diameter.

Porphyrins: Heterocyclic compounds which consist of macrocycles. Synthetic porphyrin dyes are used in solar cells. Petroleum is "fingerprinted" by analysis of trace amounts of nickel and vanadyl porphyrins.

Prebiotic Chemistry: Deals with the spontaneous chemical reactions which may have led to the formation of biomolecules and life on earth.

Radioactive waste: The byproduct of nuclear reactions that gives off (usually harmful) radiation.

Radioactivity: The spontaneous emission of matter or energy from the nucleus of an unstable atom (the emitted matter or energy is usually in the form of alpha or beta particles, gamma rays, or neutrons).

Recycling: System of collecting, sorting, and reprocessing old material into usable raw materials.

Refrigerants: Cooling substances, many of which contain CFCs and are harmful to the earth's ozone layer.

Renewable energy: Energy resources such as windpower or solar energy that can keep producing indefinitely without being depleted.

Smog: A dense, discolored radiation fog containing large quanities of soot, ash, and gaseous pollutants such as sulphur dioxide and carbon dioxide, responsible for human respiratory ailments. Most industrialised nations have implemented legislation to promote the use of smokeless fuel and reduce emission of toxic gases into the atmosphere.

Solar energy: Energy derived from sunlight.

Solid waste: Non-liquid, non-gaseous category of waste from non-toxic household and commercial sources.

Soot: A fine, sticky powder, comprising mostly of carbon, formed by the burning of fossil fuels.

Spent wash: The dark brown coloured wastewater produced by the distillery sector. It contains organic pollutants.

Spinosad: A reduced risk insecticide, which does not bioaccumulate, volatilise, or persist in the environment.

Supercritical fluids: Obtained by subjecting small molecules, like carbon dioxide, to appropriate temperature and pressure to attain the critical point at which the molecules possess the character of a fluid which is a cross between a liquid and a gas.

Syngas: Produced from biodegradable municipal solid waste through the processes of incineration and gasification. It is used for heating, cooking, etc.

Teratogens: Chemicals which affect reproduction.

Toxic emissions: Poisonous chemicals discharged to air, water or land.

Toxic waste: Garbage or waste that can injure, poison, or harm living things, and is sometimes life-threatening.

Trans-fats: Play a role in raising blood cholesterol levels. They are present in crackers, cookies, pastries and deep fried fast foods. They raise bad (LDL) cholesterol, but do not raise good (HDL) cholesterol.

Uranium: A heavy, radioactive metal (atomic number 92) used in the explosion of nuclear weapons.

Volatile organic compounds (VOCs): This class of chemicals includes a plethora of organic molecules, aliphatic and aromatic hydrocarbons, halogen-containing compounds, etc. They are released into the atmosphere by natural processes or anthropic activities (accidental spillouts from chemical plants, or during transport, storage or use of low-boiling organic products). They are co-responsible for the formation of photochemical smog.

Windpower: Power or energy derived from the wind (via windmills, sails, etc.).

Zero emission vehicles: Vehicles (usually powered by electricity) with no direct emissions from tailpipes or fuel evaporation.

MULTIPLE CHOICE QUESTIONS

1. India launched a Green Court, to make polluters pay damages, in the year
   (a) 2010 (b) 2007
   (c) 2008 (d) 2005
2. An agreement was made between India and the World Bank to advance India's green growth agenda (biodiversity conservation and pollution control) in the year
   (a) 2006 (b) 2008
   (c) 2009 (d) 2010
3. Which of the following affect biodiversity?
   (i) Environmental pollution
   (ii) Ocean acidification
   (iii) Climate change
   Select the correct answer using the codes given below:
   (a) (i) and (iii)
   (b) (ii) and (iii)
   (c) None of the above
   (d) All of the above
4. Morphine, nicotine and cocaine are examples of
   (a) Alkaloids (b) Terpenoids
   (c) Steroids (d) Flavonoids
5. Bioactive compounds consisting of five carbon isoprene units are
   (a) Coumarins (b) Carotenoids
   (c) Terpenoids (d) Flavonoids
6. Carotene is found in
   (a) Lemon (b) Carrot
   (c) Radish (d) Turnip
7. The red, orange and yellow colours of leaves are due to
   (a) Aldehydes (b) Tannins
   (c) Lignins (d) Carotenoids
8. The steroid responsible for plaque deposition in atherosclerosis is
   (a) Cholesterol (b) Ergosterol
   (c) Stigmasterol (d) Calciferol
9. Sex hormones are
   (a) Carbohydrates (b) Steroids
   (c) Vitamins (d) Alkanes
10. Too much consumption of tea or coffee can result in deficiency of
    (a) Calcium (b) Vitamin C
    (c) Albumin (d) Vitamin B_{12}
11. Compounds used to convert animal hides to leather are
    (a) Lignins (b) Enzymes
    (c) Tannins (d) Lipids
12. Glycolipids contain an alcohol, alongwith a
    (i) Phosphate group (ii) Fatty acid
    (iii) Protein (iv) Carbohydrate
    Choose the correct option using the codes given below:
    (a) (i) and (iii) (b) (i) and (iv)
    (c) (ii) and (iii) (d) (ii) and (iv)

13 The sour taste of vinegar is due to
    (a) Citric acid (b) Acetic acid
    (c) Tartaric acid (d) Lactic acid

14. The chemical which smells of bananas is
    (a) Isoamyl acetate (b) Allyl hexanoate
    (c) Limonene (d) Benzaldehyde
15. Most insects communicate by secreting chemicals known as
    (a) Globulins (b) Pheromones
    (c) Porphyrins (d) Glutelins
16. Petroleum is fingerprinted by analysis of nickel and vanadyl

(a) Nucleic acids (b) Coenzymes
(c) Porphyrins (d) Polysaccharides

17. Chlorophyll is a porphyrin containing
(a) Magnesium (b) Calcium
(c) Iron (d) Tin

18. Carbohydrates serve as structural elements in plants in the form of
(a) Starch (b) Glycogen
(c) Glucose (d) Cellulose

19. Which of the following is/are responsible for the sweet taste of fruits?
(i) Maltose (ii) Ribose
(iii) Lactose (iv) Fructose
Select the correct answer using the codes given below:
(a) (ii) and (iv) (b) (i) and (iii)
(c) (i) only (d) (iv) only

20. Proteins are polymers of
(a) Fatty acids
(b) Dicarboxylic acids
(c) Amino acids
(d) Hydroxy acids

21. Which protein-sugar pair is present in milk?
(a) Casein, sucrose (b) Casein, lactose
(c) Ferritin, maltose (d) Albumin, glucose

22. Which of the following are examples of denaturation of protein?
(i) Boiling of egg
(ii) Curdling of milk
(iii) Cutting of nails
(iv) Straightening of curly hair
Select the correct answer using the codes given below:
(a) (iii) and (iv) (b) (i) and (ii)
(c) (i), (ii) and (iv) (d) (i), (iii) and (iv)

23. In which of the following pairs do both members contain the protein, Keratin?
(a) Hair, nails (b) Nails, eyes
(c) Skin, tongue (d) Bones, blood

24. In the oxidation of fats and oils, which part of the molecule is attacked by atmospheric oxygen?
(a) Ester lingakes
(b) Carbon-carbon double bonds
(c) Hydroxyl goups
(d) Carboxyl groups

25. Partial hydrogenation of a fat or an oil does which of the following?
(a) Produces fatty acid salts.
(b) Decreases the degree of fatty acid unsaturation.
(c) Decreases the melting point.
(d) Increases the number of fatty acid residues present.

26. Fish like mackerel, tuna and salmon contain
(a) Omega-2 acids (b) Omega-3 acids
(c) Omega-4 acids (d) Omega-5 acids

27. Gall bladder stones are deposits of
(i) Calcium (ii) Glucose
(iii) Cholesterol
Choose the right option.
(a) (i) and (ii) (b) (i) and (iii)
(c) (i) only (d) (iii) only

28. ATP stands for
(a) Adenosine triphosphate
(b) Alanine triphosphate
(c) Adrenalin triphosphate
(d) Asparagine triphosphate

29. An error in base sequence in a gene that is reproduced during DNA replication is called
(a) Catenation (b) Transformation
(c) Mutation (d) Transcription

30. Which of the following is *not* a structural subunit of a nucleotide?
(a) A nitrogen-containing heterocyclic base
(b) A pentose sugar
(c) An amino acid
(d) A phosphate

31. Which of the following elements are present in the backbone of a nucleic acid molecule?
(i) Nitrogen (ii) Oxygen
(iii) Carbon (iv) Hydrogen
Select the correct answer using the codes given below:

(a) (ii), (iii) and (iv) (b) (i), (iii) and (iv)
(c) (iii) and (iv) (d) (iii) only

32. Ribozymes are enzymes made of
(a) Deoxyribonucleic acids
(b) Ribonucleic acids
(c) Fatty acids
(d) Hydroxy acids

33. What happens to substrate molecules at an enzyme active site?
(a) They become covalently bonded to the enzyme
(b) They become catalysts
(c) They react with oxygen in the air
(d) They undergo change to a desired product

34. Chloroquine is an
(a) Antibiotic (b) Antibacterial
(c) Antimalarial (d) Antifungal

35. Which of the following is an example of an anticoagulant drug?
(a) Aspirin (b) Morphine
(c) Penicillin (d) Streptomycin

36. Antihypertensive drugs
(a) relieve pain
(b) suppress cough
(c) reduce blood pressure
(d) elevate the mood

37. Beta-carotene is a precursor for which of the following vitamins?
(a) Vitamin-A (b) Vitamin-E
(c) Vitamin-D (d) Vitamin-K

38. The precursor for Vitamin D is
(a) Folic acid (b) Cholesterol
(c) Thiamine (d) Ascorbic acid

39. The vitamin which can be biosynthesised by the body is
(a) Vitamin-A (b) Vitamin-C
(c) Vitamin-D (d) Vitamin-E

40. The vitamin which aids in clotting of blood is
(a) Vitamin-B_1 (b) Vitamin-K
(c) Vitamin-C (d) Vitamin-D

41. The biochemical substances that prepare the body for puberty are called
(a) Hormones (b) Enzymes
(c) Vitamins (d) Minerals

42. Which of the following are neurotransmitters?
(i) Acetylcholine (ii) Dopamine
(iii) Serotonin (iv) Glycine
Choose the correct option.
(a) (i) and (iii) (b) (ii) only
(c) (iv) only (d) (i), (ii) and (iii)

43. Which of the following solvents is used in refrigeration and is a known culprit of ozone layer depletion?
(a) Benzene
(b) Chlorofluorocarbon
(c) Carbon tetrachloride
(d) Chloroform

44. Supercritical fluids used in Green Chemistry are a cross between
(a) a liquid and a gas
(b) a solid and a gas
(c) a liquid and a liquid
(d) a gas and a gas

45. Immobilised solvents used in Green Chemistry are solvents which are
(a) frozen
(b) bound to a polymer
(c) volatile
(d) supercritical

46. Hazardous effects of a substance can be reduced by
(i) increasing its bioavailability
(ii) minimising its bioavailability
(iii) using protecting groups
(iv) using solvents
Select the correct answer using the codes given below:
(a) (i) only (b) (ii) only
(c) (iii) and (iv) (d) None of the above

47. Detection, measurement and monitoring of chemicals in the environment is done through
(a) Analytical Chemistry
(b) Medicinal Chemistry
(c) Combinatorial Chemistry

(d) Prebiotic Chemistry

48. Polysaccharide polymers are better than most other polymers because
    (i) their accident potential is negligible.
    (ii) they are biodegradable after their useful life is over.
    (iii) they are obtained from non-renewable feedstocks.
    (iv) they have no significant toxic effects on human health and the environment.

    Which of the above are correct statements ?

    (a) (i), (ii) (b) (ii), (iv)
    (c) (i), (ii), (iv) (d) (i), (ii), (iii)

49. Production of chemicals from waste biomass
    (i) leads to conservation of non-renewable resources
    (ii) facilitates global warming
    (iii) contributes to soil pollution
    (iv) reduces air pollution

    Which of the above statements are *not* true?

    (a) (i), (iv) (b) (ii), (iii)
    (c) (i), (ii), (iii) (d) (i), (iii), (iv)

50. Spinosad is a reduced risk insecticide which
    (a) does not bioaccumulate
    (b) volatilises
    (c) persists in the environment
    (d) is highly toxic to humans

51. Synthesis of many different substances simultaneously at a fast rate can be done by means of
    (a) Physical chemistry
    (b) Green chemistry
    (c) Combinatorial chemistry
    (d) Environmental chemistry

52. Enzymes are used to
    (i) improve the performance of detergents
    (ii) make beer
    (iii) process food
    (iv) digest food

    Which of the above are true?

    (a) (iv) (b) (i), (iv)
    (c) (i), (iii), (iv) (d) (i), (ii), (iii), (iv)

53. Biocatalysts are highly selective. This selectivity leads to
    (a) more side reactions
    (b) lower yields
    (c) purer products
    (d) more environmental waste

54. The biomaterial used to replace large sections of bones is
    (a) Titanium
    (b) Alumina
    (c) Polyurethane
    (d) 316L stainless steel

55. Which of the following are true?
    (i) Silicones are used in cosmetic surgery.
    (ii) Carbon is used in heart valves.
    (iii) Polyurethanes are used for pace maker leads.
    (iv) Arsenic is used to fill bone voids.

    Choose the correct option.

    (a) (i), (ii), (iii), and (iv)
    (b) (i), (ii) and (iv)
    (c) (ii), (iii) and (iv)
    (d) (i), (ii) and (iii)

56. Which of the following are examples of Biomimetics?
    (i) Birds inspiring aircraft design
    (ii) Seashells inspiring ceramics
    (iii) Butterflies inspiring making of artificial silk
    (iv) Lizards inspiring 'Gecko tape'

    Select the correct answer using the codes given below:

    (a) (i) and (iii) (b) (ii) and (iv)
    (c) (i), (ii) and (iv) (d) (i), (iii) and (iv)

57. Replacing the use of polyethylene in coated papers by a biopolymer can help
    (a) eliminate oxygen in compost
    (b) eliminate plastic scraps in compost
    (c) eliminate carbon dioxide in compost
    (d) eliminate water in compost

58. Metal ions which act as enzyme inhibitors are

(a) Hg^{2+}, Cd^{2+}, Pb^{2+} (b) Ca^{2+}, Sr^{2+}, Ba^{2+}
(c) Na^{+}, K^{+}, Ca^{2+} (d) Mg^{2+}, Fe^{2+}, Cu^{2+}

59. The outbreak of *itai itai* disease in Japan occurred due to
    (a) Mercury poisoning
    (b) Lead poisoning
    (c) Cadmium poisoning
    (d) Arsenic poisoning
60. Genetic defects were observed in babies whose mothers had consumed mercury contaminated fish from Minamata Bay (Japan) in 1953. This mercury was in the form of
    (a) Mercuric chloride
    (b) Methyl mercury
    (c) Mercuric sulphide
    (d) Isoprpryl mercury
61. Carbon monoxide poisoning can be cured by
    (a) exposing the affected person to fresh oxygen
    (b) eating butter
    (c) drinking lemon-water
    (d) consuming multivitamin tablet
62. Chronic exposure of plants to sulphur dioxide leads to chlorosis, which is
    (a) blackening of buds
    (b) burning of roots
    (c) bleaching of green leaves
    (d) retarded growth
63. The biochemical effects of ozone and PAN appear mostly to arise from the generation of
    (a) Carbocations (b) Free radicals
    (c) Carbanions (d) Carbenes
64. Cyanide exerts its toxic action by inhibiting the production of
    (a) ATP (b) Oxygen
    (c) Haemoglobin (d) Bile acids
65. The pesticide, DDT
    (i) attacks the central nervous system
    (ii) accumulates in the fatty membrane surrounding nerve cells
    (iii) persists in the environment
    (iv) contains chlorine

    Which of the above statements are true?
    (a) (i), (ii), (iii), (iv) (b) (i), (ii), (iii)
    (c) (i), (iv) (d) (i), (iii), (iv)
66. Consider the following chemicals:
    (i) Vinyl chloride
    (ii) Ethylene dichloride
    (iii) Beta-naphthylamine
    (iv) Aspirin

    Which of the above is/are not carcinogenic?
    (a) (ii) (b) (iv)
    (c) All of the above (d) (i), (ii), (iii)
67. Consider the air pollutants given below:
    (i) Carbon dioxide (ii) Nitrogen dioxide
    (iii) Ammonia (iv) Sulphur dioxide

    Which of the above is/are not obtained by combustion?
    (a) (i), (ii) and (iv) (b) (ii) only
    (c) (iii) only (d) (iv) only
68. Forest fires are natural sources of
    (a) Carbon monoxide
    (b) Hydrocarbons
    (c) Hydrogen sulphide
    (d) Nitrogen dioxide
69. Smog containing high levels of sulphur dioxide is called
    (a) Photochemical smog
    (b) Reducing smog
    (c) Oxidising smog
    (d) Acidic smog
70. The gas accidentally released by Union Carbide pesticide plant (Bhopal gas tragedy) in 1984 was
    (a) Carbon monoxide
    (b) Sulphur dioxide
    (c) Methyl isocyanate
    (d) Methane
71. The primary releases of radioactive nuclides in the Fukushima Daiichi (Japan) nuclear disaster were those of
    (a) Iodine-131 & Calcium
    (b) Cesium-137 & Barium

(c) Iodine-131& Chlorine
(d) Iodine-131& Cesium-137

72. The most polluted places in India are
(a) Gwalior and Bhopal
(b) Vapi and Sukinda
(c) Jharkhand and Nasik
(d) Surat and Rampur

73. The Trade Pact with US and France will help India fight global warming with
(a) Heat energy (b) Microwave energy
(c) Nuclear energy (d) Electrical energy

74. The Secretariat of the Convention on Biological Diversity, coordinating the International Year of Biodiversity campaign, was based in
(a) Stockholm (b) Vienna
(c) Montreal (d) Rotterdam

75. The year declared as the International Year of Biodiversity was
(a) 2009 (b) 2010
(c) 2006 (d) 2008

76. Match List I (Type of Toxin) with List II (Example) and select the correct answer using the code given below the lists:

List I (Type of Toxin)	**List II** (Example)
A. Carcinogen	1. Cyanide ion
B. Neurotoxin	2. LSD
C. Hallucinogen	3. Benzo (α) pyrene
D. Metabolic poison	4. Atropine

Code

	A	B	C	D
(a)	4	3	2	1
(b)	3	4	2	1
(c)	4	1	3	2
(d)	2	4	3	1

77. The nausea and stupor of drunkenness (from consumption of ethyl alcohol) are not caused by alcohol itself but by
(a) Acetaldehyde (b) Acetic acid
(c) Methyl alcohol (d) Hydrochloric acid

78. Substances that poison the nervous system are called
(a) Nucleosides (b) Nucleoties
(c) Neurotoxins (d) Nervotins

79. The hallucinogenic chemical commonly known as "Grass" or "Hash" is
(a) LSD (b) Marihuana
(c) Mescaline (d) Methaqualone

80. Which of the following are corrosive poisons?
(i) Sulphuric acid
(ii) Phosgene
(iii) Sodium hydroxide
(iv) Ozone
Choose the correct option.
(a) (i) and (iii) (b) (ii) and (iv)
(c) (ii) (d) All of the above

81. Smokers suffer chronically from the effects of
(i) Carbon dioxide
(ii) Nitrogen dioxide
(iii) Carbon monoxide
(iv) Sulphur dioxide
Select the correct option.
(a) (i) and (iv) (b) (ii) and (iii)
(c) (iii) only (d) (i) only

82. Which of the following are metabolic poisons?
(i) Nicotine (ii) Cyanide ion
(iii) Arsenic (iv) Carbon monoxide
Choose the correct answer.
(a) (ii), (iii) and (iv) (b) (i), (iii) and (iv)
(c) (ii) and (iii) (d) (i) and (ii)

83. Which of the following is not correctly matched?

Neurotoxin	**Normal Contact**
(a) Morphine	Opium
(b) Caffeine	Coffee
(c) Nicotine	Tobacco
(d) Atropine	Muscle relaxant

84. Mutagens are chemicals that affect the
(a) Hereditary pattern
(b) Enzyme action
(c) Nerves
(d) Sense of judgement

85. LSD stands for
    (a) Low sugar drugs
    (b) Lithium sodium diodes
    (c) Lysergic acid diethylamide
    (d) Low sodium dish

86. The compound disulfiram (Antabuse) sometimes used to treat chronic alcoholism leads to accumulation of
    (a) Water (b) Acetaldehyde
    (c) Formic acid (d) Carbon dioxide

87. The toxins which cross the placenta and harm the fetus are called
    (a) Mutagens (b) Carcinogens
    (c) Teratogens (d) Hallucinogens

88. Taxol, the well-known drug against cancer, is extracted from the tree
    (a) Yew (b) Neem
    (c) Oak (d) Banyan

89. Insulin controls the
    (a) level of urea in the blood
    (b) level of sugar in the blood
    (c) amount of calcium in the blood
    (d) amount of iron in the blood

90. **A.** Enzymes catalyse chemical reactions in biological systems.
    R. Enzymes are proteins.
    Select the correct option.
    (a) Both A and R are correct
    (b) A is correct and R is incorrect
    (c) Both A and R are correct and R is the correct explanation of A
    (d) Both A and R are correct but R is not the explanation of A

91. The human body contains the maximum amount of
    (a) Water (b) Proteins
    (c) Iron (d) Lipids

92. Fat soluble pigments are
    (a) Flavonoids (b) Alkaloids
    (c) Lignins (d) Tannins

93. The drug "hashish" is obtained from the flowers of
    (a) Rose (b) Hibiscus
    (c) Jasmine (d) Hemp

94. The urine samples of diabetic patients contain
    (a) Fructose (b) Glucose
    (c) Sucrose (d) Starch

95. Match List I with List II:

List I	List II
A. Alkaloid	1. Menthol
B. Terpenoid	2. Ergosterol
C. Steroid	3. β-Carotene
D. Carotenoid	4. Cocaine

Select the correct code.

Code

	A	B	C	D
(a)	4	1	2	3
(b)	3	1	4	2
(c)	2	4	1	3
(d)	2	1	4	3

96. Carcinogenesis can be caused by
    (i) X-rays (ii) Dyes and paints
    (iii) Benzene (iv) Soot and tar
    Select the correct option.
    (a) (i)
    (b) (i) and (iv)
    (c) (i), (iii) and (iv)
    (d) (i), (ii), (iii) and (iv)

97. Heroin can be prepared by acetylation of
    (a) Quinine (b) Caffeine
    (c) Morphine (d) Berberine

98. Which of the following is not correctly matched?
    (a) Nicotine Antibacterial
    (b) Caffeine Stimulant
    (c) Reserpine Antihypertension agent
    (d) Quinine Antimalarial drug

99. **A.** Sucrose is sweet in taste.
    R. Sucrose gives glucose and fructose on hydrolysis.
    Select the correct option.
    (a) A is correct and R is incorrect.
    (b) Both A and R are incorrect.

(c) Both A and R are correct and R is the correct explanation of A.
(d) Both A and R are correct but R is not the explanation of A.

100. Anaemic patients are deficient in
(a) Iodine (b) Iron
(c) Calcium (d) Potassium

101. Which of the following are non-renewable energy resources?
(i) Natural gas (ii) Coal
(iii) Syngas (iv) Petroleum
Select the correct answer using the codes given below:
(a) (ii) and (iv) (b) (i) and (iii)
(c) (i), (ii) and (iv) (d) (i), (ii) and (iii)

102. Which of the following statement(s) is(are) true for greenhouse gases?
(i) Greenhouse gases are green in colour.
(ii) Greenhouse gases are responsible for global warming.
(iii) Nitrogen oxide, carbon dioxide, and water vapour are greenhouse gases.
Select the correct option.
(a) (i) (b) (iii)
(c) (i) and (iii) (d) (ii) and (iii)

103. Burning of coal (the worst environmental pollutant) releases large amounts of
(i) Methane (ii) Nitrogen oxides
(iii) Sulphur dioxide (iv) Carbon dioxide
Select the correct answer.
(a) (ii) and (iii) (b) (ii), (iii) and (iv)
(c) (i) and (iv) (d) (i), (iii) and (iv)

104. Which energy resource is not used in Ralegaon Siddhi, the home village of the social worker and activist Anna Hazare?
(a) Biogas (b) Solar energy
(c) Wind energy (d) Nuclear energy

105. Which place in the world has the highest natural gas reserves?
(a) Iran (b) Saudi Arabia
(c) Russia (d) UAE

106. The most chemically polluted city in the world is
(a) Linfen (China)
(b) Delhi (India)
(c) Bangalore (India)
(d) Dzerzhinsk (Russia)

107. Which one of the following is the greenest city in India?
(a) Chandigarh (b) Bhopal
(c) Patna (d) Pune

108. Which three places hold more than 50% of the world's coal deposits?
(i) China (ii) India
(iii) USA (iv) Russia
Select the correct answer using the codes given below:
(a) (i), (ii) and (iii)
(b) (i), (iii) and (iv)
(c) (ii), (iii) and (iv)
(d) (i), (ii) and (iv)

109. The most polluted industrial cluster in India is in
(a) Faridabad (b) Ankleshwar
(c) Surat (d) Durgapur

110. Which country is the largest producer of heavy water that is used in nuclear reactors to slow down the speed of neutrons?
(a) India (b) Germany
(c) Japan (d) France

111. The Indian city which has the largest number of roof-top solar water heaters is
(a) Jaipur (b) Agra
(c) Bangalore (d) Ahmedabad

112. The largest solar power producer in the world is
(a) Burma (b) India
(c) Iran (d) Germany

113. The World Geothermal Congress (2010), organised by the International Geothermal Association, was held in
(a) New Zealand (b) Sweden
(c) Indonesia (d) China

114. Which one of the following Indian states is a leading harvester of wind energy?
    (a) Tamil Nadu
    (b) Punjab
    (c) Haryana
    (d) Madhya Pradesh

115. Stockholm Convention is an international treaty concerned with
    (a) depletion of ozone layer
    (b) elimination and restriction of the production and use of persistent organic pollutants
    (c) climate change aimed at fighting global warming
    (d) conservation of biodiversity

ANSWER KEY

1. (a)
2. (d)
3. (d)
4. (a)
5. (c)
6. (b)
7. (d)
8. (a)
9. (b)
10. (a)
11. (c)
12. (d)
13. (b)
14. (a)
15. (b)
16. (c)
17. (a)
18. (d)
19. (d)
20. (c)
21. (b)
22. (c)
23. (a)
24. (b)
25. (b)
26. (b)
27. (d)
28. (a)
29. (c)
30. (c)
31. (a)
32. (b)
33. (d)
34. (c)
35. (a)
36. (c)
37. (a)
38. (b)
39. (c)
40. (b)
41. (a)
42. (d)
43. (b)
44. (a)
45. (b)
46. (b)
47. (a)
48. (c)
49. (b)
50. (a)
51. (c)
52. (d)
53. (c)
54. (b)
55. (d)
56. (c)
57. (b)
58. (a)
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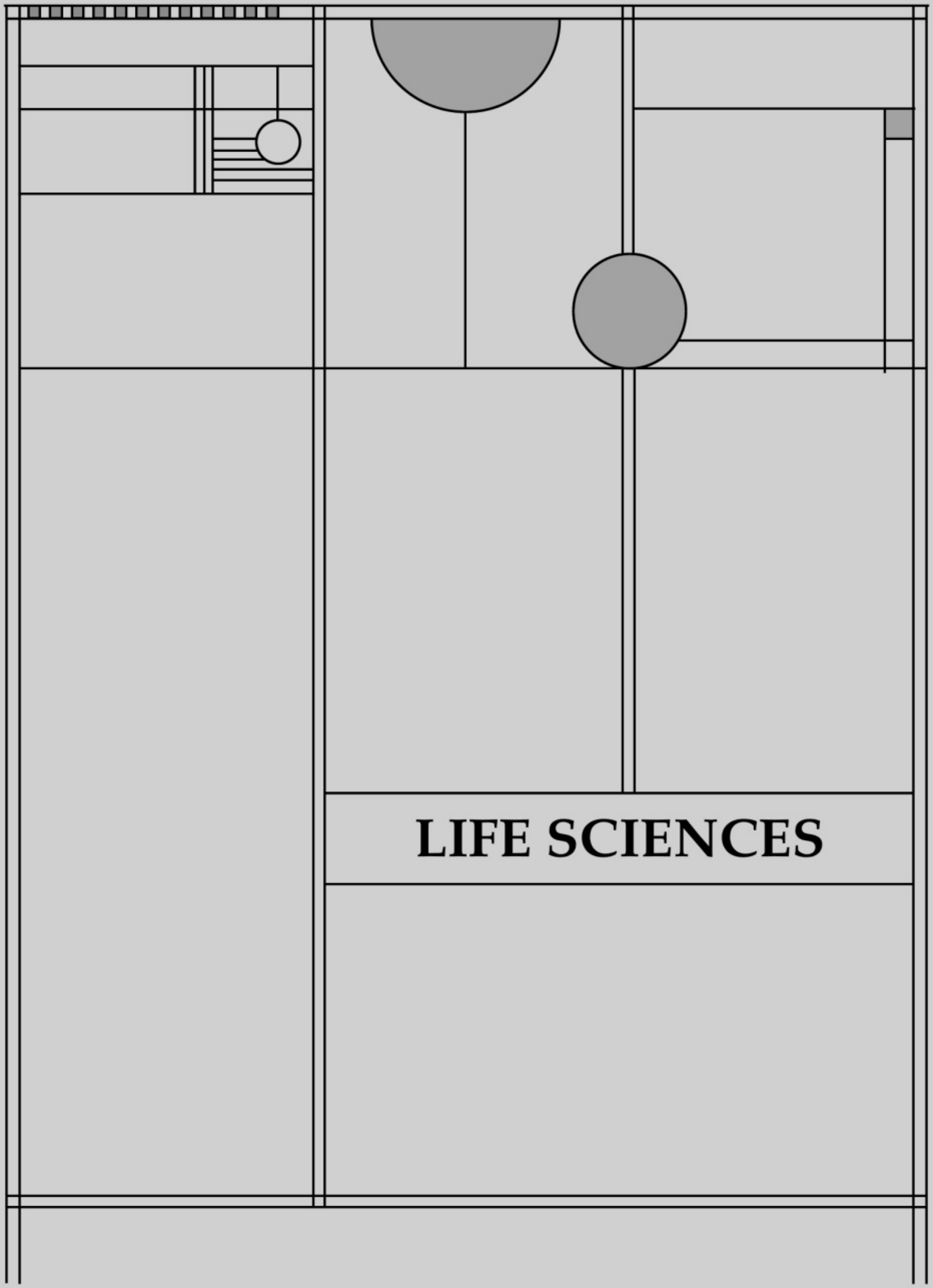
PART-B



LIFE SCIENCES

SECTION–I

BIOLOGY

CHAPTER ONE

ORIGIN AND EVOLUTION OF LIFE

B.1.1 ORIGIN OF LIFE

We salute the spirit of inquisitiveness of man, which gave birth to the discipline of science. The same spirit of questioning also led man to often wonder how life or the first organism came into existence. This quest led him to find answers to how, when and where life originated.

For centuries, it was believed that life originated *de novo*. In addition several other scientific and non-scientific theories were also put forward. Some of them are:

(i) **Theory of special creation:** (or Biblical Theory) – It was put forward by Father Suarez, a Spanish Monk.

(ii) **Theory of spontaneous generation** (or **Abiogenesis**): (Gr, '*a*' – absence, "*bios*" – life, "*genesis*" – origin) or origin from non-living matter.

(iii) **Theory of Panspermia or Cosmozoic Theory:** According to this theory, life came from some other planet. It's still believed to be true by some scientists like Wikramsinghe, Francis Crick and Leslie Orgel.

(iv) **Biogenesis:** **Francesco Redi** and Louis Pasteur laid the foundation for the **Theory of Biogenesis,** which propounded that living organisms arise from pre-existing ones and not from non-living matter.

(v) **Chemosynthetic Theory or Chemogeny:** This theory proposed that first form of life originated from inorganic chemical elements by **formative** action of some external physical force viz. lightening or cosmic rays, etc. It was put forward by **A.I. Oparin** and **J.B.S. Haldane** and the experimental evidence was provided by **Stanley Millar** & **Harold Urey**. For example, **Mighi meteorite in Ukraine** and analysis of another meteorite content viz. **Murchison, Victoria in Australia** by space biologists also revealed similar composition indicating that similar processes are still occurring elsewhere in space. However, in this case, although the presence of amino acids and polynucleotide are similar to DNA, these are of chemical origin and therefore have **identical** strands instead of **complementary** strands.

B.1.2 EVOLUTION OF LIFE

Although, the above mentioned theories explained how life must have originated on early primitive earth about 3.5 billion years ago, but it did not give any information about how the biological diversity arose.

Again, there were different views about how this must have happened. Some of the dominant thoughts were: (i) Greek Theories (ii) Pre-modern Theories and (iii) Modern Theories. Among the Modern Theories, the following two are most popular.

Theory of Inheritance of Acquired Characteristics

This theory was proposed by famous French naturalist **Jean Baptiste Lamarck**. It propounded that the characters were acquired by the organisms due to an "inner need" or "desire" of the organism and these acquired characters were then inherited. This theory was subsequently rejected.

Theory of Natural Selection

Charles Darwin, who is better known as the "**Father of Evolution**" was the architect of this world famous theory, which charmed both the scientists as well as laymen. This theory took shape when Darwin was aboard H.M.S. Beagle, the famous ship, for a voyage planned for world exploration. According to him, the **struggle for existence**, due to limited availability of resources, led to the **survival of the fittest** or **natural selection**. (For more details, see Chapter 14, Section B.14.1)

Adaptive radiation in **Darwin's Finches** (a type of sparrow-like bird) in Galapagos Islands on the west coast of South America and **Industrial melanism** (darkening of wings) in black peppered moth, *Biston betularia* of Manchester, United Kingdom, are **classical examples of natural selection**.

B.1.3 EVIDENCES OF EVOLUTION

The word "evolution" is derived from the Latin word "evolvere" which means to "unroll" or "unfold". Thus, the theory of Organic Evolution states that it's a kind of gradual unfolding or formation of more complex, advanced and present day forms from simple and primitive organisms living in the past, millions of years ago. There are various evidences available to prove this point. viz.

(a) **Morphological and Anatomical Evidences**

(b) **Embryological evidences**

(c) **Paleontological (Fossils) evidences:** The study of fossils (paleontology) is the best and **most direct conventional** type of evidence, e.g., the fossil of *Archaeopteryx**. ("Archaeo" means primitive and "ptera" means wings in *Latin*) is a classical example of evolution of birds from reptiles, because it contains features of both the forms. Similarly, the world famous fossil of "Lucy" (*Australopithecus afarensis*) shows that "bipedal" locomotion arose for the first time in ancestral man here and finally led to the development of erect "modern" man.

(d) **Biogeographical evidences**

(e) **Biochemical evidences:** The most convincing evidence of common ancestry comes from similarities of certain biomolecules viz. composition of protoplasm, enzymes, cytochrome 'C' (respiratory pigment present in all eukaryotic cells), blood serum proteins, hemoglobin, insulin, etc. **The degree of molecular homology is more in closely related forms and vice versa,** e.g., **amino acid sequence for cytochrome 'C' of humans and chimpanzee is identical**.

(f) **Genetic evidences or Molecular evidences:** These are the **latest observable** tools in determining the phylogenetic relationships between organisms and allow **molecular comparisons** even between very uncommon relatives with no morphological, behavioural, physiological or ecological relationships e.g., bacteria and humans. Some of the molecular tools used to prove evolutionary relationships are:

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* Incidentally, *Archaeopteryx* has been recently replaced by *Xiaotingia zhengi* species, an *Archeopteryx*-like therapod from China (by Zing Xu *et al*. in Nature (2011).

Amber fossils are one of the **best preserved fossils.**

- Amino acid analysis or sequencing e.g., Hb, Mb sequencing in para and orthologous species.
- Nucleotide sequence analysis (data from 5S ribosomal RNA)
- DNA hybridisation
- **Restriction enzymes:** which cleave DNA into fragments at particular sites like ECORI from *E. coli.* They allow comparisons among DNA of different species
- RFLPs (**R**estriction **F**ragment **L**ength **P**olymorphisms)
- **Mitochondrial DNA and microsatellites, etc**.

  (Also refer to Chapter 14, Section B.14.1)

> *Cockroaches* have one of the best basic "designs". That is why it has survived for millions of years without any change in its organisation, as also the *bacteria* present in hot springs or ice!

CHAPTER TWO

CELL BIOLOGY

B.2.1 PROPERTIES

The question, “What’s life?” may appear quite naïve, because although a phenomenon called, “life” is quite obvious, at the same time it’s also very complex.

A living organism is not merely a collection of basic atoms or molecules or elements viz. carbon, hydrogen, oxygen, nitrogen, sulphur, etc. but there are certain basic highlights or properties or **characteristics** which describe it.

Some of these are:

1. **Cellular Organisation:** All organisms consist of one or more cells bounded by a membrane, which carry out basic activities of living organisms.
2. **Ordered Complexity:** All living things are complex but at the same time highly ordered. The cells are not only organised but arranged in a hierarchical order which becomes more complex at each level e.g., the cells are grouped into tissues, which form organs, which in turn form organ systems and finally an organism.
3. **Reproduction:** “Life begets life”, i.e., living organisms produce their own kind and pass hereditary molecules to their offsprings. **This is the most distinctive feature of living organisms**.
4. **Growth and Development:** Most living organisms are multicellular i.e., a single cell divides to form a number of cells, which increases both in size and number. Not only this, they also undergo specialisation e.g., they may form specialised cells viz. neurons, etc.
5. **Regulation or Homeostasis:** All organisms maintain a relatively “constant internal environment” by various mechanisms e.g. the water and salt concentration of body fluid, or blood glucose level or the degree of acidity or alkalinity are all kept at a stable or constant level.
6. **Energy Processing:** All organisms need energy, which they use for performing various kinds of work. This energy comes from the breakdown of various organic nutrients viz. carbohydrates, proteins, fats, etc. This energy is then used for carrying out various activities viz. locomotion or breathing.

7. **Sensitivity or Response to the environment:** All living organisms are sensitive to various stimuli viz. light, temperature, etc. and then produce appropriate response to these stimuli of their environment e.g., plants grow towards light or we close our eyes in bright light or withdraw our hands from a hot object.
8. **Evolutionary Adaptation:** All living organisms interact with the other organisms as well as non-living environment. Both of these have a great effect on their survival. Therefore, in order to live successfully, they evolve adaptations to their environment e.g., animals living in cold environment have a thick coat of fur while those living in desert possess dry and scaly skin.

B.2.2 THE CELL

A cell **is** made up of repeating basic units, which inspired Robert Hooke to coin the term "cell". All living organisms are made up of these basic units of life i.e., "cells".

The cell has same central position in biology as the atom in physics.

This concept was further developed by two German biologists—M. Schleiden and Theodore Schwann in 1839, who formulated the "**Cell Theory**". According to this theory, cells are **basic units of structure** as well as **function**. Later on, one more idea that all the cells arise from **pre-existing cells** was added by Rudolph Virchow, a German Physician, in 1855.

All cells have some **basic** features:

(i) A selectively permeable membrane—**the plasma membrane**

(ii) A jelly-like, semi fluid substance—the **cytosol** (All the cellular organelles are present in this cytosol forming the matrix of the cell.)

(iii) Genes in the form of DNA (the hereditary molecule)

(iv) Tiny, rounded structure meant for protein synthesis—**the ribosomes**

There are **two** types of cells—**prokaryotic and eukaryotic** cells. They differ in one major aspect, which is the **location of DNA**. In **prokaryotes**, (Gr.—**pro** before and **karyon**—nucleus), viz. found in bacteria and blue-green algae,(1) DNA is **naked** and concentrated in a region that is **not membrane bound**, called the **nucleoid region**. (2) Further, they have **no membranous organelles** except ribosomes. These cells are more primitive.

On the other hand, **eukaryotes**, **(Gr. 'eu'—true, 'karyon'—nucleus) which includes** higher organism's viz. plants, animals and other multi-cellular organisms, have most of their DNA present in a **double membrane bound organelle**, called **nucleus**. Further, they have a number of other membrane-enclosed organelles as well.

B.2.3 THE CELLULAR ORGANELLES

The cellular organelles are listed in the form of a table (Table B.2.1).

Table B.2.1

Eukaryotic Cell Structures and their Functions

Structure	Description	Function
1. Plasma membrane	Phospholipid bilayer with embedded proteins	Regulates what passes into and out of cell; cell-to-cell recognition; connection and adhesion; cell communication
2. Nucleus	Structure (usually spherical) that contains chromosomes and is surrounded by double membrane	Instructions for protein synthesis and cell reproduction; contains genetic information

Contd.

Structure	Description	Function
3. Chromosome	Long threads of DNA that form a complex with protein	Contain *hereditary information* used to direct synthesis of proteins
4. Nucleolus	Site of genes for rRNA synthesis	Synthesis of rRNA and ribosome assembly
5. Ribosomes	Small, complex assemblies of protein and RNA, often bound to ER	*Sites of protein synthesis*
6. Endoplasmic Reticulum (ER)	Network of internal membranes	Intracellular compartment forms *transport* vesicles; participates in lipid synthesis and synthesis of membrane or secreted proteins
7. Golgi apparatus	Stacks of flattened vesicles	Packages proteins for export from cell; forms secretory vesicles
8. Lysosomes	Vesicles derived from Golgi apparatus that contain hydrolytic digestive enzymes	*Digest worn-out organelles* and cell debris; digest material taken up by endocytosis
9. Microbodies	Vesicles that are formed from incorporation of lipids and proteins and that contain oxidative and other enzymes	Isolate particular chemical activities from rest of cell
10. Mitochondria	Bacteria-like elements with double membrane	**_“Power plants” of the cell,*_ sites of oxidative metabolism**
11. Chloroplast	Bacteria-like elements with double membrane surrounding a third, thylakoid membrane containing chlorophyll, a photosynthetic pigment	**_Sites of photosynthesis*_**
12. Cytoskeleton	Network of protein filaments	Structural support; cell movement; movement of vesicles within cells
13. Flagella (cilia)	Cellular extensions with 9+2 arrangement of pairs of microtubules	Motility or moving fluids over surfaces
14. Cell wall	Outer layer of cellulose or chitin; or absent	Protection; support

Table B.2.2

A Comparison of Prokaryotic, Animal, and Plant Cells

	Prokaryote•	Animal•	Plant*
Exterior Structures			
Cell wall	Present (protein-polysaccharide)	Absent	**_Present (cellulose)*_**
Cell membrane	Present	Present	Present
Flagella/cilia	Flagella may be present	May be present (9+2 structure)	Absent except in sperm of a few species (9+2 structure)
Interior Structures			
Endoplasmic reticulum (ER)	Absent	Usually present	Usually present
Ribosomes	Present	Present	Present
Microtubules	Absent	**Present•**	Present

Contd.

	Prokaryote•	**Animal•**	**Plant***
Centrioles	Absent	Present•	Absent
Golgi apparatus	Absent	Present	Present
Nucleus	**Absent$^{\Delta}$**	Present	Present
Mitochondria	Absent	Present	Present
Chloroplasts	Absent	Absent	**Present***
Chromosomes	Single; circle of DNA	Multiple; DNA-protein complex	Multiple; DNA-protein complex
Lysosomes	Absent	Usually present	Present
Vacuoles	Absent	Absent or small	*Usually a large single vacuole**

B.2.4 CELL DIVISION

Growth and development are characteristic features of cells. During this period, the cells increase both in **numbers and size**. Most of the living organisms are made up of number of cells therefore, if a single cell has to become multicellular, they must undergo repeated cycles of growth and division. Such cycle is known as **cell cycle**. This helps the organism not only to increase the cell number and size but also transfer genetic information from parents to offsprings (sexual reproduction).

Hence, cell division is important in a living organism for

(a) Growth and development
(b) Reproduction and
(c) Tissue renewal (in mature organisms)

The cell cycle is essentially divided into **two periods—(a) Interphase and (b) Division phase**

(a) Interphase

1. It's known as **non-division** phase or **resting phase**.
2. It lasts for more than 95% of the duration of cycle.
3. Although it's called as resting phase, but the cell is **biochemically very active.** During this phase, the cell prepares itself for the ensuing cell division and synthesises various biomolecules including two similar copies of DNA.
4. It's divided into **G_1 phase** ("First-Gap"), the **S phase** (Synthesis) and **G_2 Phase** (Second Gap)

(b) Division phase

1. It is also known as **M-phase** or Mitosis phase.
2. It lasts for only 5% of the duration of cycle.
3. The **division** phase consists of two phases —**M-phase** (or Mitosis phase) with division of nucleus or **karyokinesis** and division of cytoplasm or **cytokinesis**. **M-phase** is further subdivided into Prophase ("pro" meaning before), Metaphase("meta"—between), Anaphase ("ana"—back) and Telophase ("end").

Howard and Pelc divided cell cycle into these four phases.

Mitosis

(In Greek, "mitos" means thread). It's a mechanism in which a cell distributes its different components in **equivalent amounts** that have already been duplicated during interphase. Therefore, it's also called as **equational division**.

Prophase

1. **The *chromatin threads*** (each chromosome is made up of two chromatin threads) become more tightly coiled or *condense* into discrete ***chromosomes***, which can be observed with a light microscope.

Metaphase (It's the longest phase of mitosis.)

1. The chromosomes are thickest and shortest because of further condensation.
2. The chromosomes become attached to the microtubules of the **mitotic spindle** at kinetochore, aligned at the **equatorial plate**, exactly in the middle of the spindle.

Anaphase (Shortest stage)

1. The **centromere* splits** causing the sister chromatids to separate. The two free chromatids now begin to move towards the opposite poles.

Telophase

1. The **polar migration** of daughter chromosomes is **complete** i.e., daughter chromosomes reach the end of the poles.
2. Daughter chromosomes also start to uncoil and become less condensed. As a result they again form chromatin threads.
3. Nuclear envelope, nucleoli, golgi complex and ER reappear. In this way two daughter nuclei form within the cell.

The nuclear division is followed by division of cytoplasm, which will result in the formation of two daughter cells.

Cytokinesis: In animal cells, cytoplasm divides by forming a **cleavage furrow** (because of absence of cell wall), whereas in a plant cell it starts with the formation of a **cell plate** at the centre, which later extends into both the sides towards the periphery.

Meiosis

Meiosis is derived from the Greek work "meioum" which means "**to diminish**". Since in this division the original chromosome number (e.g., $2n = 46$) present in the parents is reduced to half (e.g., $n = 23$) in the daughter cells, it's also known as **reductional division**. Another special feature of this type of division is the **separation of homologous chromosomes** or sister chromosomes and not their halves (i.e., **chromatids**). Thirdly, meiosis is observed in **sexually reproducing organisms**. Since, sexual reproduction involves union of male **gametes** (spores in plants or sperms in animals) and female gametes (ovules in plants and ova in animals), the chromosome number is doubled and will continue to duplicate every time the cell undergoes meiosis. But, this does not happen in nature! Because, the **chromosome number is halved** during meiosis to keep it constant in a particular species or race.

It involves two divisions—(a) **Meiosis I**, and (b) **Meiosis II**

Meiosis shows many such unique features which are summarised in Fig. B.2.1.

(a) Meiosis I

Prophase I

It's far more complex than mitosis and is a long drawn process. In some, it may last for days (e.g., human male—24 days) or even months or several years (e.g., human female till puberty 15–16 years). It's further subdivided into five stages characterised by the following features:

1. Leptotene (Gr. "leptos" meaning thin, "nema"—meaning thread)

(a) The chromosomes become more apparent under microscope as **thin, elongated threads** (hence the name) aligned very close to each other. They show **bead-like thickenings** at regular intervals known as **chromomeres**.

(b) Nucleus increases in size.

2. Zygotene (Gr. "zygon"—adjoining)

Homologous chromosomes, which are **sister chromosomes**, one coming from the male parent and other from the female parent, are aligned and undergo **pairing**. This pairing is known as **synapsis**. It can begin at scattered points but progresses in such a fashion that the homologous chromosomes are **exactly** paired chromomere-by-chromomere and

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*** The two chromatids or arms of chromosomes are attached at a point called as centromere.**

gene-by-gene. This pairing of homologous chromosomes is known as **synapsis** forming **synaptonemal complex.**

3. Pachytene (Gr. "pachus"—thick)

(a) By the mid-stage, the nucleus contains half the number of chromosomes, because each unit is now a **bivalent** ("bi" meaning "two" referring to **two homologous chromosomes**) or a **tetrad** ("tetra" means "four" referring to **four chromatids**). Thus the two non-sister homologous chromosomes with their four arms or chromatids are intimately paired during this stage.

(b) Another important development which occurs during this phase and has far-reaching effects with respect to formation of **recombinants** is "**crossing-over**". The two **non-sister** homologous chromosomes exchange segments containing genetic material, resulting in new combinations.

4. Diplotene

Intimately paired chromosomes start repelling each other during this stage and begin to separate. But since separation is not complete, the homologous chromosomes remain united at certain points (points of inter-change) forming **chiasmata** (Gr. **chiasma—cross-piece**).

These are regarded as morphological expression of a phenomenon called **crossing-over** or **recombination**.

5. Diakinesis (Gr. "dia"—across)

(a) The contraction of chromosomes is further enhanced. As a result the "tetrads" are more evenly distributed in the nucleus.

(b) The "chiasmata" moves towards the ends, known as **terminalisation**. Hence the homologous chromosomes are held only at their terminal ends, resulting in **ring-shaped** chromosomes or **x-shaped** chromosomes.

Metaphase-I

It's similar to mitosis, in the sense, that nuclear envelope breaks down and spindle fibres become attached to the **centromere of homologous chromosomes** (and not the kinetochore of same chromosome).

The "bivalent" chromosomes become arranged at the equatorial plate.

Anaphase–I

Homologous chromosomes and not chromatids (with their sister chromatids united by centromere) move towards opposite poles.

Thus the chromosome number **is halved** because only half the number of chromosomes found in mother cell reach each pole.

Telophase-I

(a) The homologous chromosomes arrive at their respective poles.

(b) The nuclear membrane and nucleolus reappear and chromosomes decondense.

(c) This is followed by cytokinesis, which results in two haploid cells.

Meiosis I is followed by **interkinesis** which is generally short-lived. In some organisms interphase between Meiosis I and II may be skipped and they may directly enter into the second meiotic division.

The second meiotic division is almost similar to mitosis except that here the chromosome number is **halved** in the daughter cells (haploid). Since, there is a **second round of cell division**, this results in separation of **sister chromatids (and not homologous chromosomes as in Meiosis I)** forming four daughter haploid cells with **unreplicated chromosomes** or **genetic material. This is because of the fact that although there are two rounds of cell division, only a single cycle of DNA replication.**

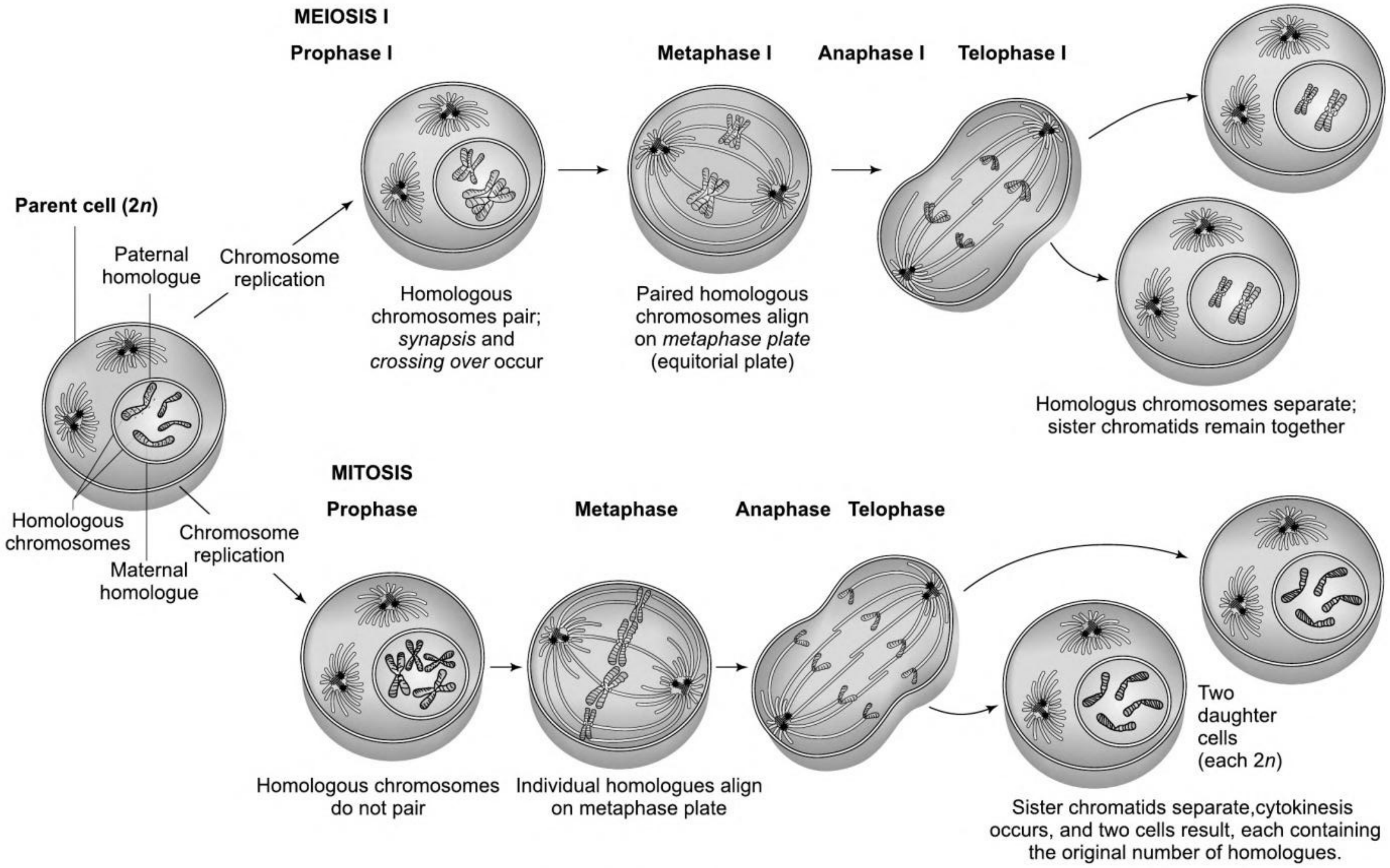
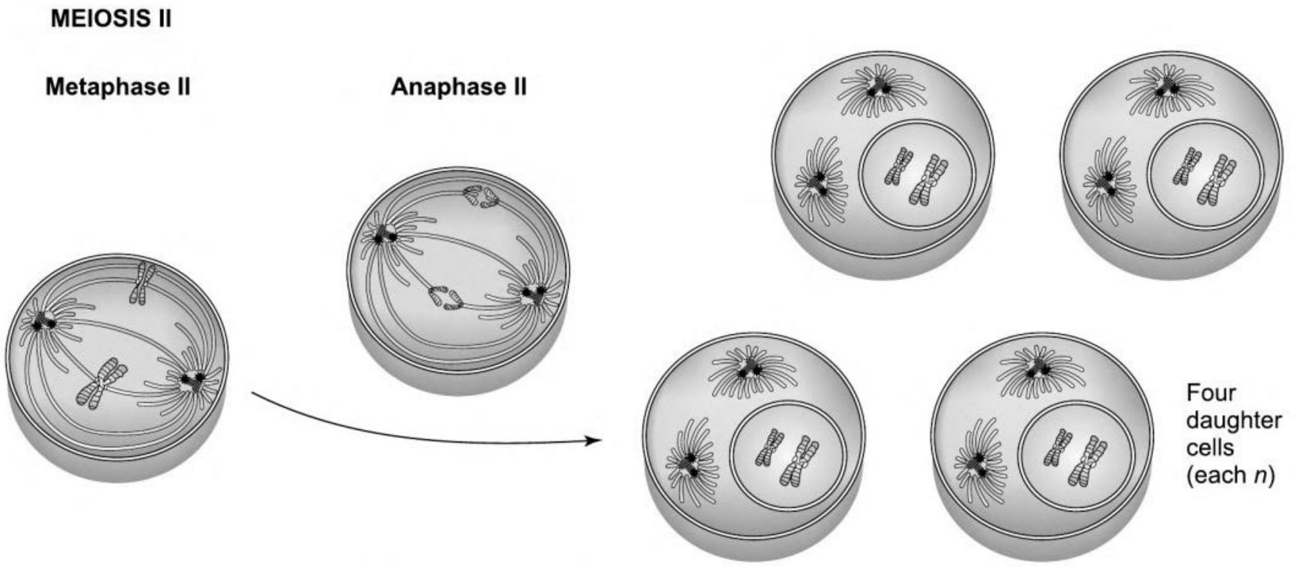

MEIOSIS I
Prophase I
Metaphase I
Anaphase I
Telophase I
Parent cell (2*n*)
Paternal homologue
Chromosome replication
Homologous chromosomes pair; *synapsis* and *crossing over* occur
Paired homologous chromosomes align on *metaphase plate* (equitorial plate)
Homologus chromosomes separate; sister chromatids remain together
Homologous chromosomes
Maternal homologue
Chromosome replication
MITOSIS
Prophase
Metaphase
Anaphase
Telophase
Homologous chromosomes do not pair
Individual homologues align on metaphase plate
Two daughter cells (each 2*n*)
Sister chromatids separate,cytokinesis occurs, and two cells result, each containing the original number of homologues.

Figure B.2.1

Comparison of Mitosis and Meiosis I

contd.


MEIOSIS II
Metaphase II
Anaphase II
Four daughter cells (each *n*)

Chromosomes align, sister chromatids separate, and four haploid cells result, each containing half the original number of homologues.

Figure B.2.1

Comparison of Mitosis and Meiosis I

B.2.4 REGULATION OF CELL CYCLE

Recent research has shown that there are **positive regulators** of cell cycle, which are proteins in nature, called **cyclin-dependent kinases** (cdks). These are complexes of kinase and a regulatory molecule called cyclin. They phosphorylate proteins to drive the cell cycle. The cell cycle can be halted at **three** check-points. The check-points are points at which the cell can assess the accuracy of the process and stop if needed. These are:

(i) G_1/S (It is a commitment to divide)
(ii) G_2/M (ensures DNA integrity) and
(iii) Spindle check-point (ensures all chromosomes are attached to spindle fibres).

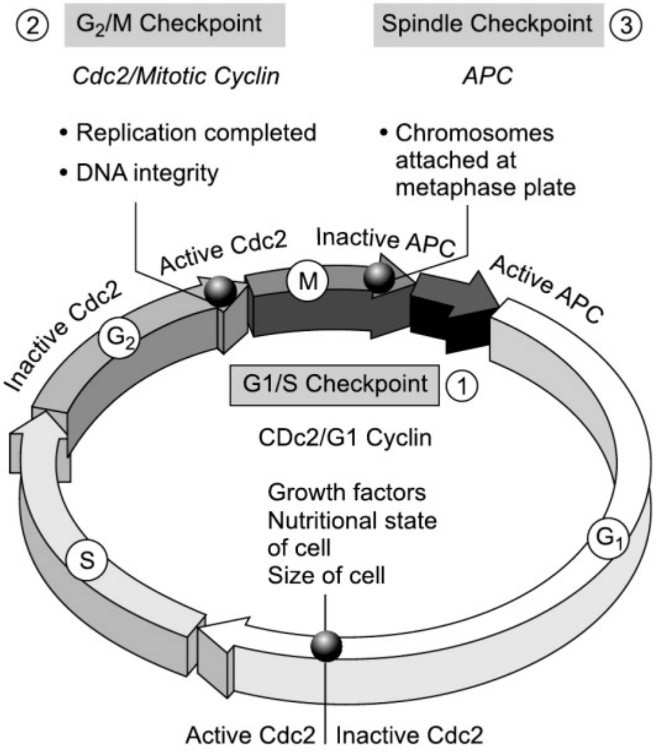

② G_2/M Checkpoint
Spindle Checkpoint ③
Cdc2/Mitotic Cyclin
APC
• Replication completed
• DNA integrity
• Chromosomes attached at metaphase plate
Active Cdc2
Inactive APC
M
Active APC
Inactive Cdc2
G_2
G1/S Checkpoint ①
CDc2/G1 Cyclin
Growth factors
Nutritional state of cell
Size of cell
G_1
S
Active Cdc2
Inactive Cdc2

Figure B.2.2

Checkpoints of the cell cycle

There can be one (e.g., yeast) to many CDK enzymes (e.g., vertebrates). These are G1 cyclin, Cdc2 kinase (now called CdK1), MPF, APC/C and Cdk, etc. In multicellular eukaryotes, in addition to Cdks, some external signals viz. **growth factors** also act on the cell cycle e.g., platelet-derived growth factor (**PDGF**).

B.2.5 CELL METABOLISM

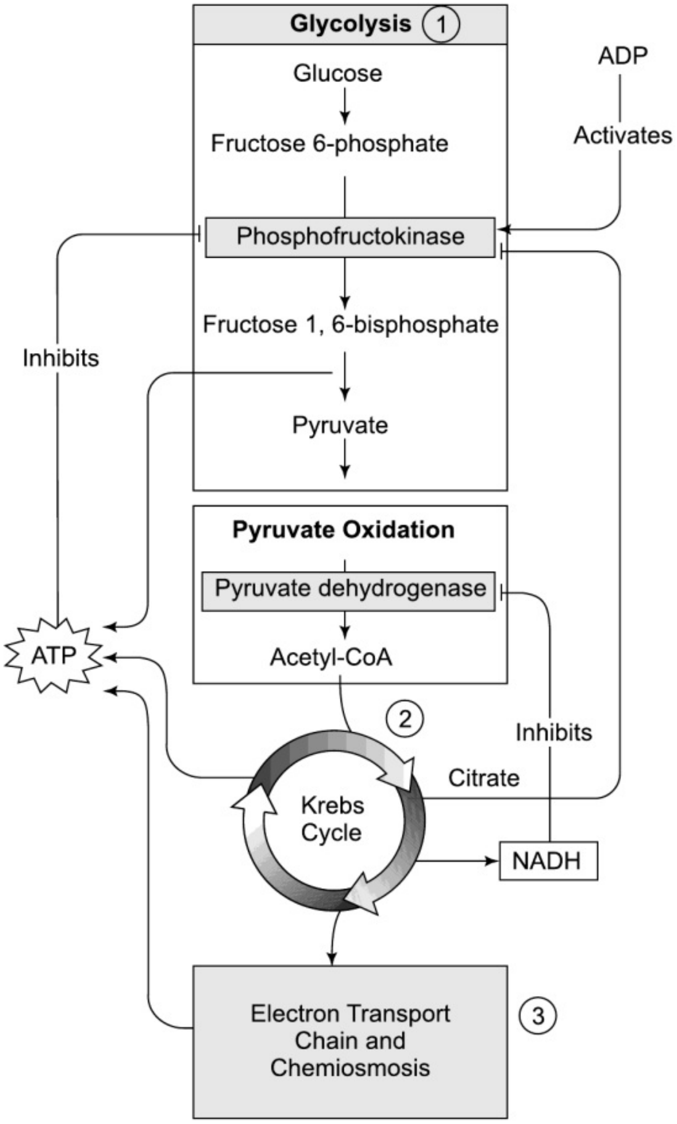

Glycolysis ①
Glucose
Fructose 6-phosphate
ADP
Activates
Phosphofructokinase
Inhibits
Fructose 1, 6-bisphosphate
Pyruvate
ATP
Pyruvate Oxidation
Pyruvate dehydrogenase
Acetyl-CoA
②
Inhibits
Citrate
Krebs Cycle
NADH
Electron Transport Chain and Chemiosmosis
③

Figure B.2.3

Cellular Respiration

B.2.6 VIRUSES

For more than four decades, viruses, were not considered as organisms, because they don't show many of the characters associated with living organisms viz. cellular structures, its own metabolism and replication, etc. But, at the same time, they were found to cause many plant and animal diseases and hence were considered to be important biologically. They were known as **filterable agents. M.W. Beijerinck**, a Dutch microbiologist coined the term, **virus** (Latin "poison") for them. They are also known as **virions** or **bacteriophage** (Gr. "bacteria", "phagein" meaning to eat bacteria).

Viruses have very simple structure with a **nucleic acid** genome encased in a **protein coat**. The genome can be RNA (e.g., TMV, Influenza, virus, etc.) or DNA (Adenovirus), which may in turn be single- or double-stranded. Most DNA viruses are double-stranded.

Viruses replicate by taking over a host's cell system and are thus **obligate intracellular parasites**.

In 1953, **W.M. Stanley**, an American Chemist, isolated the Tobacco Mosaic Virus (TMV) in pure crystalline form, which could be kept for long periods of time.

B.2.7 VIROIDS

Recently, some sub-viral particles have been discovered viz. **viroids** and **prions**. Viroids are tiny, **naked** molecules of **circular RNA**, with only a few hundred nucleotides. There are important infectious agents of some plant diseases viz. potato spindle tuber diseases in U.S.A., (Incidentally, the term **viroid** was coined by **T.O. Diener** for the causative agent of this disease), **Cadang-cadang** disease of coconut palm in Philippines and **Chrysanthemum stunt** (CS), etc. They use host proteins to replicate.

B.2.8 PRIONS

For decades, scientists had been baffled by a peculiar group of fatal brain diseases. These diseases showed a peculiar property of showing their symptoms sometimes as late as 30–40 years after the infection. These diseases include scrapie disease in sheep, Creutzfeldt-Jacob disease (CJD) in humans, bovine spongiform encephalopathy (BSE) or "mad cow"[*] disease in cattle, "Kuru" disease in villagers of New Guinea, etc. These diseases are collectively known as transmissible spongiform encephalopathies (**TSEs).**

In the early 1970s, physician **Stanley Psrusiner** began to study TSEs and despite repeated trials, he could find no evidence of nucleic acid or viruses in the infectious TSE preparations. He, then concluded, as **Alper** and **Griffith** had earlier suggested, that the infectious agent was a **protein**. He named it as a **prion**, - a "proteinaceous infectious particle". Prions consist of **misfolded proteins** that cause related cellular proteins to also misfold.

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[*] The outbreak of "mad cow" disease in England made headlines in 1990s and recently in Germany.

CHAPTER THREE

GENETICS

Genetics is study of science of **genes, heredity** and **variation in living organisms**. Heredity is the cause of similarity between individuals and variation is the cause of differences between individuals. Genetics deals with transmission of characters from parents to offspring and the molecular structure and function of genes. The study of genes is done at three levels.

- Transmission Genetics
- Population Genetics
- Molecular Genetics

B.3.1 TRANSMISSION GENETICS

The two most fundamental questions in biology are— what is the nature of genetic material and how is it transmitted from parents to offsprings? The fact that living things inherit traits from their parents has been used in prehistoric times to improve crop plants and animals through selective breeding. However modern genetics only began with the work of **Gregor Mendel**. His breeding experiments in pea plants revealed that hereditary characteristics are determined by discrete factors (genes) that are transmitted to the next generation.

The Laws of Inheritance

The study of science of genetics begins with the work of Gregor Mendel. He was a clergyman and a teacher. He performed his own experiment on garden pea. He restricted his attention to the single character and kept **pedigree** records for each plant. Mendel studied the nature of inheritance in plants and presented his work in 1885 in the paper "**Experiments on Plant Hybridisation**". The importance of his work did not get noticed until 1890s, after his death. The advantages of garden pea (*Pisum sativum*) as experimental system were:

(i) The characters were readily observable.
(ii) Plants were easy to grow and **self fertilise** before the flowers opened.

Mendel worked with 14 **pure breeding** varieties and selected seven pairs of characters and propounded the following laws:

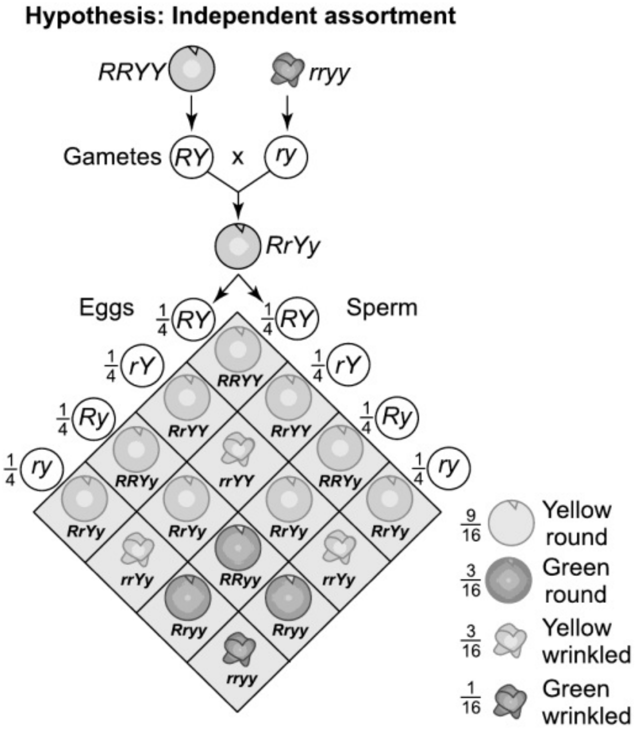
1. *The law of dominance*: Mendel stated that the hereditary characters are determined by pair of factors (**genes)** in an individual. In a **monohybrid cross** all the plants in **F_1 generation** showed only one character but in F_2 the other character appears. The character in F_1 genera-

tion is **dominant** and the one which expresses in F_2 generation is **recessive** e.g., the cross between two homozygous parents (P), one with two dominant alleles for tall plant (TT) and the other with two recessive alleles for dwarf plant (tt). The phenotype of the offspring in F_1 generation is tall plant but the genotype is Tt. The F_1 heterozygote produces four kinds of gametes. When this plant self-pollinates, the T and t egg and sperm cells combine randomly to form ¼ TT (tall), 2/4 Tt (tall) and ¼ tt (dwarf) offspring. The F_2 generation has 1:2:1 genotypic ratio and 3:1 phenotypic ratio.

Parents	TT	×	tt
	(Tall)		(Dwarf)
F_1		Tt	
		(Tall)	
F_2			
gametes	T		t
T	TT		Tt
	(Tall)		(Tall)
t	Tt		tt
	(Tall)		(Dwarf)

2. *The law of segregation or purity of gametes*: These pair of characters in an individual segregate from each other during the formation of gametes. In one pair of contrasting character **alleles** segregate in 3:1 **phenotypic ratio** and 1:2:1 **genotypic ratio.**
3. *The law of independent assortment*: In the formation of gametes the segregation of one pair of allele is independent of the segregation of any other pair of alleles and therefore gametes containing all possible combination of these alleles will be produced in equal numbers. In a **dihybrid** cross the F_2 phenotypic ratio is 9:3:3:1.

After 100 years of Mendel's first publication, the three scientists Hugo de Vries, Carl Correns and Erich von Tschermak re-examined and verified Mendel's laws and science of genetics was launched.



Deviation from Mendel's Law of Inheritance

Allelic interactions Dominance is sometimes incomplete. In such cases heterozygotes (progeny) show intermediate between those of two homozygotes (parents), the gene is said to be governed by **incomplete dominance**. Sometime, the two alleles at a locus produce two different phenotypes that both appear in heterozygotes, a phenomenon called **co-dominance** e.g., ABO blood group in human. Some alleles have multiple phenotypic effects, the allele is called **pleiotropic**.

Non-allelic interactions Different genes also interact and affect the expression of each other in many different ways. Such interactions are also called **non-allelic interaction**. One interaction where one gene affects the expression of another gene is called **epistasis.** The gene which is expressed is known as **epistatic** and the gene whose expression is masked is known as **hypostatic**. The most challenging problem is the expression of complex phenotypes that are caused by many interacting genes and the environment.

What are Genes?

The unit of heredity is a gene. It is sequence of nucleotides that codes the amino acid sequences of polypeptides or for RNA. **Beadle and Tatum** proposed the **one-gene-one-enzyme** theory, which states that the production of a given enzyme is under the control of a specific gene. If there is change in the gene, the enzyme will not be synthesised properly or will not be made at all. Scientists later on discovered that one gene is responsible for synthesis of one polypeptide i.e., **one-gene-one-polypeptide**. Genes are subjected to random mutations that give rise to new alleles. An allele that is present in most individuals in nature is considered to be **"wild type**". Other alleles of that gene are called as **mutant alleles**. The wild type and mutant alleles reside at the same **locus** and are inherited according to Mendel's laws. Many genes have **multiple alleles**. Multiple alleles increase the number of possible phenotypes e.g., coat color in rabbits is determined by one gene with four alleles. Any rabbit with C allele (paired with any one of the four) is dark gray, and rabbit with cc is albino (Table B.3.1).

The Chromosomal Theory of Inheritance

In the year 1903, **W.S. Sutton** and **T. Boveri** independently suggested that the cell nuclei contain specifically stained thread like chromosomes. These are visible only at specific stages of cell cycle associated with cell division (see Biology, Chapter 2, Fig. B.2.1). Each cell was found to have a characteristic number of chromosomes **(diploid)** with distinct size and shape, called **Karyotype**. Karyotype is similar for all the cells of an organism, except the gamete contain half the number of usual chromosome number **(haploid**).

The correlation between this reduction in the chromosome number to half (haploid) in the gametes, and the Mendel's prediction of allelic reduction in gametes led Sutton and Boveri to propose that genes are carried by chromosomes. This is the basis of **the chromosomal theory of inheritance**. The variable range of the chromosome numbers from 1 in Bacteria to about 200 in some higher eukaryotes. Over the same range of organisms, the number of genes vary from about 10^3 to 10^5.

In 1910 **T.H. Morgan**, studying the fruit fly *Drosophila melanogaster* gave the evidence that gene resides on the chromosomes. He also demonstrated that the segregation of the white-eye trait is associated with the segregation of the X chromosome, now called **X-linked inheritance**.

Linkage and Crossing Over

Individual chromosomes may carry hundreds or even thousands of genes. If two genes are located relatively close together on the same pair of chromosome, they generally will not segregate independently. Such genes, which are inherited together, are called **Linked genes**. The linkage of genes was first discovered by W. Bateson in 1905, in sweet pea (*Lathyrus odoratus*). However sometimes there is exchange between homologous chromosomes during **crossing over**. The greater the distance between two genes on a chromosome greater is the chance that a crossing over will take place between them. Chromosome maps can be constructed based on the frequency of crossing over between genes. Such genetic, or linkage maps provide approximation of the position of the genes on the chromosome.

Cytoplasm organelles such as plastids and mitochondria contain small numbers of genes. In many

Table B.3.1

Inheritance of coat color in rabbits: Different combinations of two alleles give different coat colors. The dominance hierarchy is $C>c^{ch}> c^h>c$.

genotypes	CC, Cc^{ch}, Cc^h, Cc	$c^{ch} c^{ch}$	$c^{ch} c^h, c^{ch}c$	c^hc^h, c^hc	Cc
phenotypes	Dark gray	Chinchilla	Light gray	Point restricted	Albino

organisms, cytoplasmic genes are inherited only from the mother because male gametes contribute only their nucleus (i.e. no cytoplasm) to the zygote at the time of fertilisation, such genes do not follow Mendel's laws of inheritance. This type of inheritance is called **non-Mendelian inheritance** or **cytoplasmic inheritance**.

B.3.2 MOLECULAR GENETICS

In 1869, **F. Miescher** isolated the compounds contained within the nuclei of a variety of cells and named it **nuclein**. Later on P. Levene discovered that there are two types of nucleic acid (the term nuclein). He concluded that there are three molecular parts, bonded together, forming repeating unit called a **nucleotide**. The genes were known to exist on chromosome and the chromosomes are composed of both proteins and DNA. It was not clear which of these, protein or DNA, is responsible for inheritance. In 1928, Fredrick Griffith discovered the phenomenon of transformation using bacteria. During transformation, the dead bacteria could transfer the genetic material to transform other living bacteria. Some of the important experiments which gave the evidences of genetic material nature is given in Table B.3.2.

DNA: a Double Stranded Helix

Watson and Crick discovered that DNA is a double-stranded, helical molecular 'ladder' with rungs of uniform length and with alternating sugar-phosphate units forming the ladder upright. Each rung pairs a purine with a pyrimidine i.e., A always pairs T and C with G. This is known as the **complementarity of the bases** (Fig. B.3.1).

The main features of the molecular architecture of the DNA molecule are:

- It is *double-stranded* helix of uniform diameter
- it is *right-handed.*
- It is *antiparallel* (the two strands run in opposite directions).
- The outer edges of nitrogenous bases are *exposed* in the major and minor groove.

The genetic material performs four important functions:

- The genetic material stores an organism's genetic information.

Table B.3.2

Some important landmarks leading to the discovery of Genetic Material

Year	Scientist	Contributions
1869	F.Miescher	Isolated DNA and called it nuclein
1920	P.Levene	Discovered that there are two types of nucleic acid
1940s	O.Avery	Gave the evidence that DNA is the hereditary material
1940s	E.Chargaff	The proportion of the bases varies in the nucleic acids of different organisms. The proportion of purine bases is always equal to the proportion of pyrimidine bases.
1950s	G.Beadle and E.Tatum	Developed the one-gene-one-enzyme theory, which states that the production of one enzyme is under the control of a particular unit of heredity or gene.
1952	A.Hershey and M.Chase	Confirmed that DNA (not protein) is the hereditary material.
1953	R.Franklin and M.Wilkins	Analyzed DNA by X-ray diffraction and concluded that bit is shaped like a helix (winding staircase).
1953	J.Watson and F.Crick	Developed double helical model of DNA

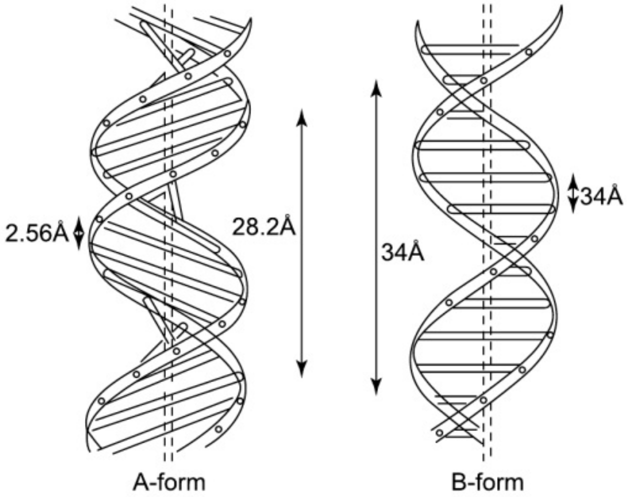


Figure B.3.1

Structure of DNA double helix

- The genetic material is susceptible to mutation.
- The genetic material is precisely replicated.
- The genetic material is expressed as phenotype.

DNA Contains Repeated Sequences

The DNA of eukaryotic organism also contains repeated sequences and is called **repetitive DNA.** One type of repetitive DNA is located at the ends of eukaryotic chromosomes. These are called **telomeres**. Every time the cell divides the telomeres shorten. When the chromosome ends become too short for the cell to function, it dies. However in some cells the enzyme **telomerase** helps rebuild the repetitive sequence after the cell division.

DNA is a Self Replicating Unit

Meselson and Stahl showed that DNA replication is **semi-conservative** i.e. each parent strand serves as template for a new strand. Thus the two replicated DNA molecules each contain one parental and one newly synthesised strand. The enzyme **DNA polymerase** catalyses the addition of nucleotides to the 3′ end of each strand. The added nucleotides are determined by complementary base pairing with the template strand. The replication complex is huge protein complex that attaches to the chromosome at the origin of replication. The replication proceeds from the origin of replication on both the strand in 5′ to 3′ direction. Many proteins assist in DNA replication. DNA **helicase** separates the two strands and **S**ingle **S**trand **B**inding proteins keep the strands from reassociating.

In prokaryotes, two interlocking circular DNAs are formed which are separated by an enzyme called DNA **topoisomerase.** The **primase** catalyses the synthesis of a short primer to which nucleotides are added by DNA polymerase. The leading strand is synthesised continuously while the lagging strand in pieces called **Okazaki fragments**, later on joined by the enzyme **ligase** (Fig. B.3.2). DNA polymerase make about one error in 10^5 bases replicated. DNA is also subjected to natural alteration and chemical damage. These errors can be repaired by three different mechanisms: proof reading, mismatch repair and excision repair. Knowledge of mechanism of DNA replication led to the development of techniques for making multiple copies of DNA sequences and for determining the nucleotide sequence of DNA molecules. (see box)

The polymerase chain reaction (PCR) makes multiple copies of a DNA sequence. PCR is a cyclic process in which a sequence of steps is repeated over and over again. Kerry Mullis developed this technique in which following steps are involved:

- Double stranded fragments of DNA are separated into single strands by heating (denaturation).
- A short artificially synthesised primer alongwith the four deoxyribonucleotide tiphosphate (d**ATP**, d**TTP**, d**CTP** and d**GTP**) and strands of **DNA** are placed in a test tube. To this mixture **DNA** polymerase is added.
- DNA polymerase catalyses the production of complementary new strands.

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Mutation

Mutation is heritable changes in DNA. Somatic mutations are passed on to daughter cells, but only germ line mutations are passed on to sexually produced offspring. In 1901, **Hugo**

de Vries studied the inheritance in evening primrose (*Oenothera glazioviana*) and observed change in one of the alleles of a gene as a result of mutation and the organism carrying it was called a **mutant**. In gene mutation also called **point mutation**, an allele of a gene changes. **Silent mutations** result in no change in amino acids, when altered mRNA is translated into a polypeptide. **Missense**, **nonsense** and **frame-shift** mutations do cause changes in the amino acids produced. **Chromosomal mutations** (deletions, duplications, inversions and translocations) involve large regions of a chromosome. Spontaneous mutations occur because of instabilities in DNA or chromosomes. Induced mutations occur when a mutagen damages DNA. Mutations, although often detrimental to an individual organism, are the raw material of evolution.

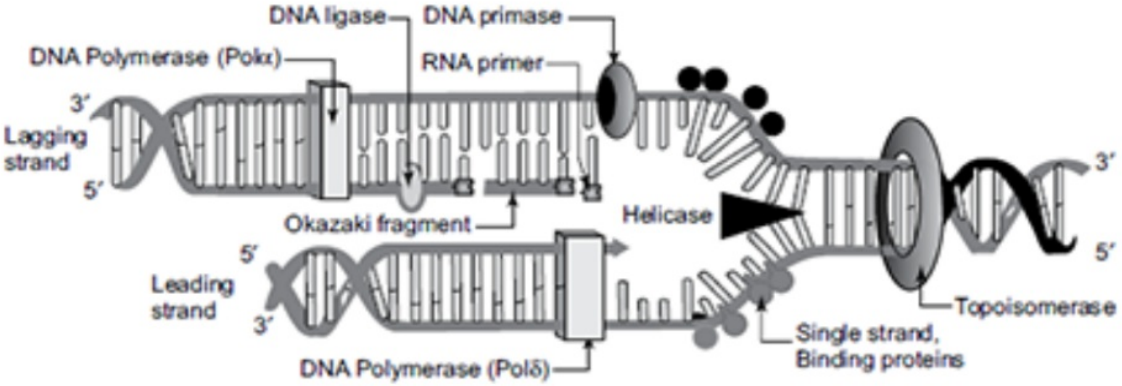


Figure B.3.2

DNA Replication: The different enzymes involved in replication of leading and lagging strand in semi-conservative manner.

Transposable Genetic Elements

These are DNA sequences which can move from one position to another in the genome. **Barbara Mc Clintock (1948)** discovered transposons in corn and received the noble prize in 1983. They are present in both prokaryotes and eukaryotes. When transposons move from one location to another, they break and mutate genes. They have played a major role in evolution and contributed to genetic diversity.

Gene Expression

In 1908 **A. Garrod**, who studied the inheritance of human disease *alkaptonuria*, linked the biochemical phenotype to a missing enzyme, and thus to an abnormal gene. He wrote a book entitled "*In born errors of metabolism*" and gave the evidence that gene expresses itself by making protein. Later on **Beadle** and **Tatum's** experiments on metabolic enzymes on the bread mold *Neurospora* led to **one-gene-one-enzyme** hypothesis, which is modified into **one-gene-one-polypeptide**; the function of gene is to code for a specific polypeptide.

The expression of a gene to form a polypeptide occurs in two major steps:

- **Transcription** copies the information of a DNA sequence (a gene) into corresponding information in an RNA sequence.
- **Translation** converts this RNA sequence into the amino acid sequence of a polypeptide.

Transcription The genetic information in the DNA is not expressed directly but is transferred via messenger RNA (mRNA). The long molecules of mRNA are assembled by complementary base pairing along one strand of the DNA helix. This process, called transcription, is catalysed by the enzyme **RNA polymerase**. RNA transcription proceeds in three steps: *initiation, elongation* and *termination*. Initiation requires a promoter, to which RNA polymerase binds. Elongation of the RNA molecule proceeds from the 5¢ to 3¢ end.

Each sequence of three nucleotides in the coding region of the mRNA molecule is the codon for a specific amino acid. Eukaryotes have three different RNA polymerases. RNA polymerase II transcribes protein coding genes (Fig. B.3.3). Most eukaryotic genes contain noncoding sequences called **introns**, which are removed from the pre-mRNA transcript. The primary transcript of a eukaryotic gene is modified while still in the nucleus. First, its 5¢ and 3¢ ends are modified; by the addition of a G cap at the 5¢ end and a poly A tail at 3¢ end. The introns are removed from pre-mRNA by **RNA spilcing**. A complex of snRNPs (small nuclear ribonucleoproteins) and enzymes, called a **spliceosome,** forms at the consensus sequences that lie between **introns** and **exons**. The spliceosome cuts out the introns and joins the exons together, results in the final mRNA strand which leaves the nucleus and travels to ribosome in the cytoplasm in the cell.

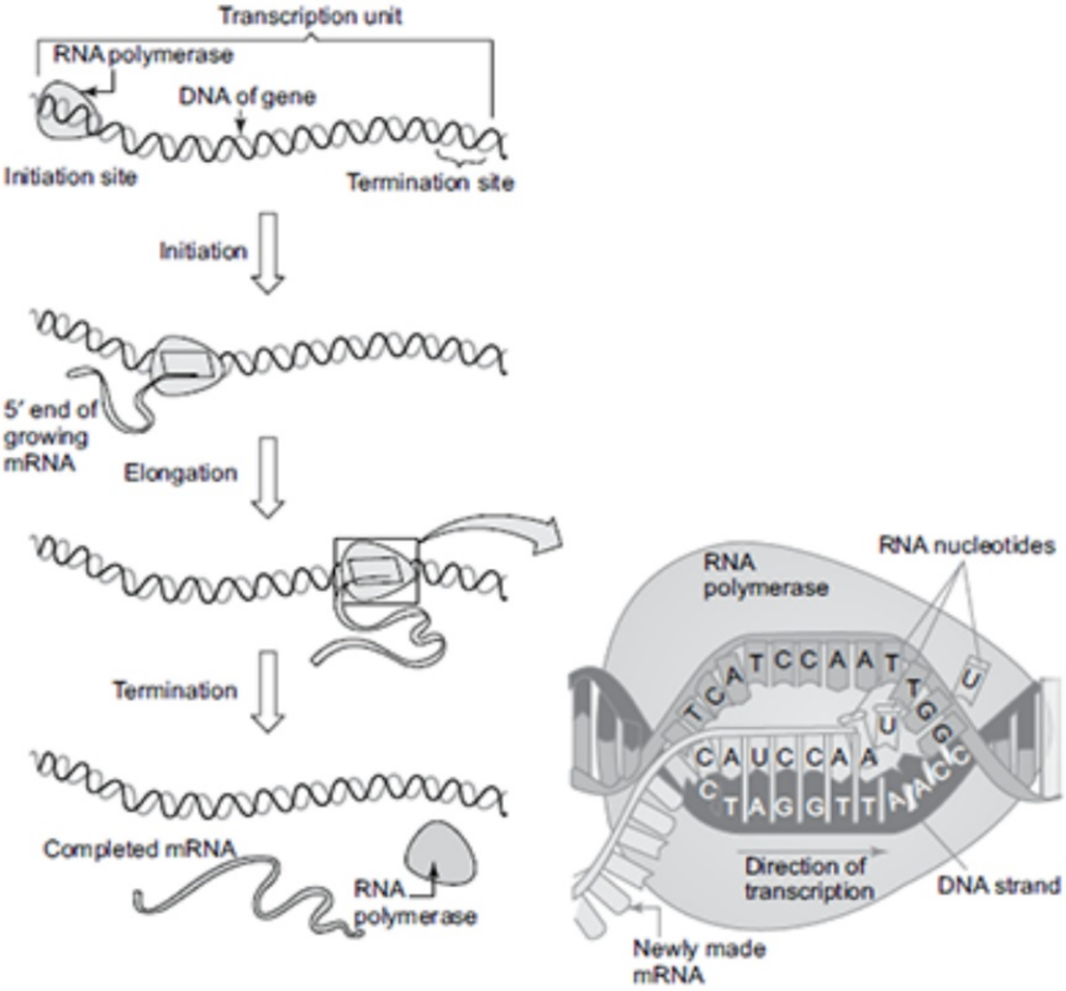

Transcription unit
RNA polymerase
DNA of gene
Initiation site
Termination site
Initiation
5′ end of growing mRNA
Elongation
Termination
Completed mRNA
RNA polymerase
RNA polymerase
RNA nucleotides
TCATCCAATTGG
U
U
CAUCCAA
CTAGGTTAACC
Direction of transcription
DNA strand
Newly made mRNA

Figure B.3.3

In 1961, while studying the DNA structure Francis Crick observed that the DNA code is made up of sequences of three nucleotide bases. Each sequence is called a **triplet**, the DNA sequences is transcribed into the complementary sequence of mRNA bases. The genetic code is a “language” of triplets of mRNA nucleotide bases (codons) corresponding to 20 specific amino acids; there are start and stop codons as well. The code is redundant (an amino acid may be represented by more that one codon), but not ambiguous (no single codon represents more than one amino acid).

Translation Protein synthesis takes place at the ribosome. A ribosome is formed of two subunits, one large and one small, each consisting of rRNA complexed with specific proteins. Another group of RNA molecule, known as transfer RNA (tRNA), is also required for protein synthesis. These molecules can carry an amino acid on one end, and they have triplet of the bases, the anticodon. The tRNA molecule is the adapter that pairs the correct amino acid with each mRNA codon during protein synthesis. There is at least one kind of tRNA molecule for each kind of amino acid found in the protein. (Fig. B.3.4).

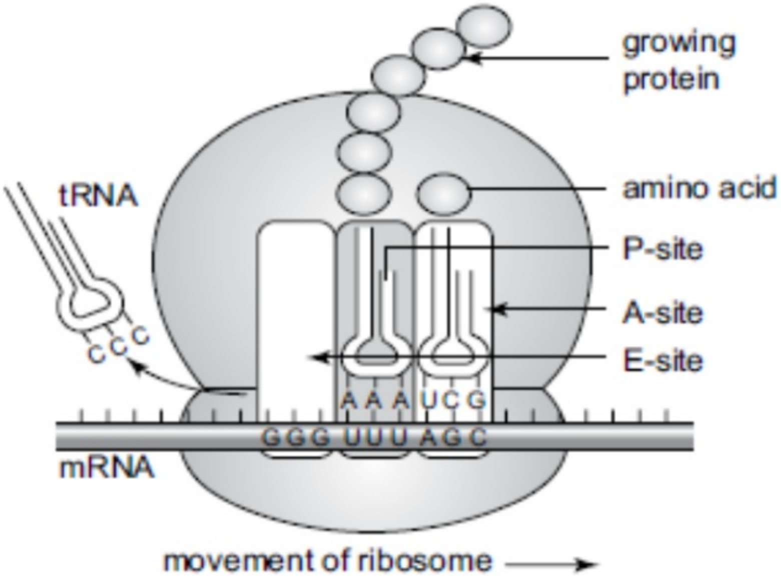


Figure B.3.4

Regulation of Gene Expression

In prokaryotes, the synthesis of some proteins is regulated so that they are made only when required. Proteins that are made only in the presence of a particular compound are called **inducible proteins** and the compound is known as **inducer**. Proteins that are made at a constant rate regardless of conditions are **constitutive** proteins. A principal means of genetic regulation in prokaryotes is the **operon** system. An operon contains not only a linear sequence of genes coding for a group of functionally related protein but also has adjacent DNA sequences known as **promoter** and **operator**. Transcription from the operon is controlled by the **promoter**, the binding site for RNA polymerase, and the operator, the binding site for the repressor. The *lac operon* is an example of an **inducible operon**. The regulatory gene codes for regulatory protein, such as **repressor**. When the repressor is attached to the DNA molecule at the operator, RNA polymerase cannot initiate the transcription of RNA. When the repressor is inactivated, RNA polymerase can attach to the DNA, permitting transcription and protein synthesis to take place. The *tryptophan operon* is a **repressible operon**, in which the presence of a co-repressor causes the repressor to bind to the operator and stop transcription.

Eukaryotic gene expression can be regulated before or during transcription, during pre-mRNA processing, and during or after translation. The regulator of DNA sequences include regulator sequences, which bind regulator proteins and activate transcription, enhancer sequences, which stimulate transcription, and silencer sequences, which bind repressor proteins and turn off transcription.

One of the most important ways of post-transcriptional regulation is alternative RNA splicing, which allows more than one protein to be made from a gene. The stability of mRNA in the cytoplasm can also be regulated. **Micro RNAs** and **RNA editing** are two recently discovered mechanism of regulation.

Homeotic genes— these are master control genes; they coordinate the action of number of genes, which, in turn, determine the development of a large region or body segment. It was first discovered in fruitflies in 1983; these genes are conserved (are the same) in organisms that are very different from one another, such as yeast, mice and human beings. Scientists have found the genes that are functionally equivalent to the *Drosophila eyeless* gene in mice.

Gene expression is also controlled by environmental signals. In prokaryotes, nutrient availability is one of the most important environmental signal in controlling transcription, e.g., lactose acts as transcription inducer of the enzymes responsible for its digestion. In eukaryotes the cell’s immediate environment is neighboring cell, hence they live in less variable environment. The two main environmental factors which control gene expression are *light* and *temperature*. Light induces production of *ribulose 1,5 biphosphate* (**R**u**BP**) *carboxylase*, plays an important role in photosynthesis, in plants. Similarly at high temperature the cell produces a group of proteins that help to stabilise internal cellular environment. These proteins are formed in both prokaryotes and eukaryotes, and are called **heat-shock proteins**.

Most frequently, eukaryotic gene expression is induced by hormones, growth factor and other related compounds. These are called **signal molecules**, as they convey signals within and between cells of a multicellular organism, inducing changes in gene expression. Two of the major classes of hormones which control gene expression are: peptide and steroid hormones.

With the molecular understanding of inheritance, an explosion of research became possible. One important development was the chain termination DNA sequencing in 1977 by **Federick Sanger**. With the help of this technology Scientists were able to read the nucleotide sequence of a DNA molecule.Through the pooled efforts of the Human Genome Project and the parallel private efforts by Celera Genomics, the sequencing of human genome was possible (see Animal World Chapter 5 Human Genetics). Another landmark in the history of molecular genetics is the discovery of restriction enzymes. The very basis of all genetic engineering and biotechnology and manipulation gene is possible because these basic understanding of DNA, the molecule of life.

B.3.3 BIOTECHNOLOGY AND GENETIC ENGINEERING

The use of scientific and engineering principles to manipulate organisms or their genes is **Biotechnology**. The classical biotechnology involves selection, hybridisation and mutation. For more than 8000 years, bacteria and yeast have been used to produce beers, vinegar, yogurt and cheese. Since ancient times, plants and animal breeders have selectively bred organisms to develop hybrids. In the late 1920s, scientists induced genetic mutation and obtained plants with new characteristics. The **United Nations Convention on Biological Diversity (UNCBD)** defines biotechnology as:

"Any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use". In other words *"Application of scientific and technical advances in life sciences to develop commercial products"* is biotechnology. A revolution took place in this area after the discovery of molecular structure of the hereditary material deoxyribonucleic acid (DNA). Another important landmark is the discovery of restriction enzymes. These are made by bacteria as a defense mechanism against viruses. **Restriction enzymes** bind to specific sites (restriction sites) of viral DNA and restrict the growth of virus by cutting the DNA into small fragments (Fig. B.3.5). These enzymes can be used to cut any DNA to produce small fragments of DNA, which can be separated by size using Gel electrophoresis. Specific DNA sequence can be identified in a gel by probes with a complementary sequence using **Southern Blotting technique**.

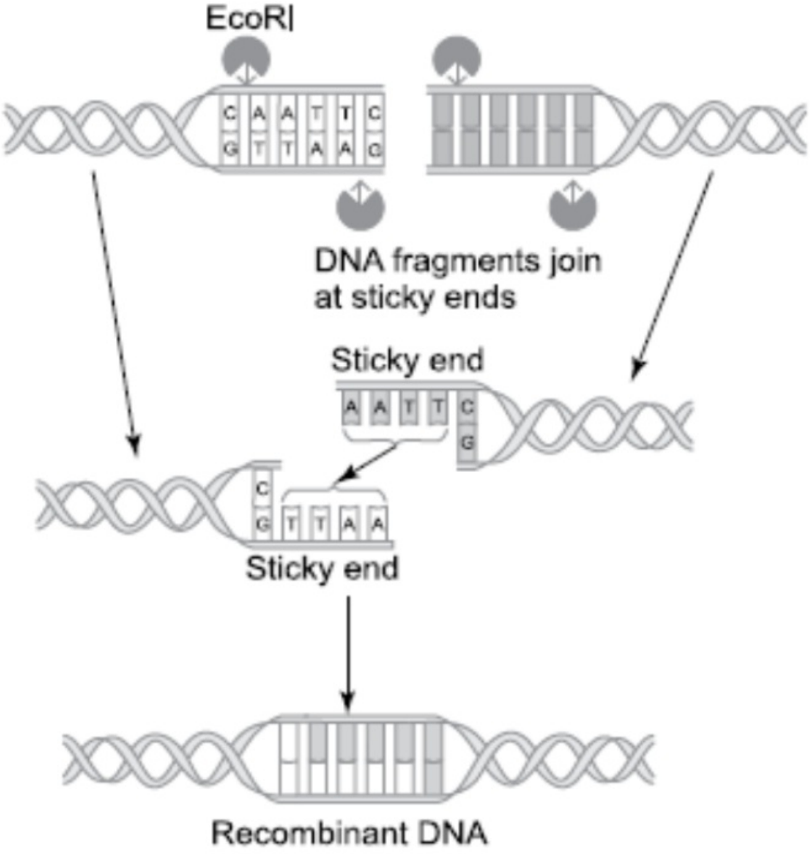


Figure B.3.5

The action of a restriction enzyme, *EcoR I* on DNA
Note: *EcoR I* gives a 'sticky' end and helps
to make recombinant DNA

Recombinant DNA is formed by the combination of two DNA from different source. One of the major goals of recombinant DNA technology is to clone a particular gene. Bacteria, yeasts and cultured plant cells are commonly used as hosts for recombinant DNA. Host cells into which recombinant DNA is inserted, or transformed, are called **transgenic cells**. To identify host cells that have taken up a foreign gene, the inserted sequence can be tagged with reporter genes, genetic markers with easily identifiable phenotypes. Expression of the foreign gene in the host cell requires, so that it can become the part of a segment of DNA, a replicon (origin and terminus of replication). There are two general ways in which the newly introduced DNA can become part of a replicon:

- It can be inserted near an origin of replication in a host chromosome after entering the host cell.
- It can enter the host cell as a part of a carrier DNA sequence called **vector** that

already has the origin of replication.

Plasmids, viruses and **artificial chromosome** (*YAC—yeast artificial chromosome, BAC—Bacterial artificial chromosome*) are all used as vector. DNA for cloning can be obtained from gene libraries, cDNA made from mRNA, and artificial synthesised DNA fragments.

Biotechnology has applications in four major industrial areas, including health care, crop production and agriculture, industrial use of crops and other products (e.g., biodegradable plastics, vegetables oil, biofuel) and environmental uses.

The several branches of biotechnology are:

- *Bioinformatics:* It is also referred to as *computational biology*, and defined as "*conceptualising biology in terms of molecules and then applying informatics techniques to understand and organize the information associated with these molecules, on a large scale*". It is an interdisciplinary field which solves biological problems using computational techniques and analysis of biological data. It plays a key role in **functional genomics, structural genomics** and **proteomics** and forms a key component in the biotechnology and pharmaceutical sector.
- *Blue Biotechnology*: This term usage is relatively rare. It is used to describe the marine and aquatic applications of biotechnology.
- *Green biotechnology*: It is the application of biotechnology to agricultural processes. It includes micro-propagation, transgenic plants and industrial agriculture. An example of this is the engineering of a plant to express a pesticide (Bt cotton).
- *Red biotechnology*: It is applied to medical processes. Designing of organisms to produce antibiotics, and the engineering of genetic cures through genetic manipulation.
- *White Biotechnology*: It also known as industrial biotechnology. It involves the use of enzymes as industrial catalysts to either produce valuable chemicals or destroy hazardous/polluting chemicals.

The investment and economic output of all these types of applied biotechnologies is termed as *bioeconomy*.

Genetic engineering: Human has altered the genomes of species for thousands of years through artificial selection. In 1986, tobacco plants were engineered to be resistant to herbicides and the first field trials of genetically engineered plants were done. The basic steps involved in genetic engineering are (Fig. B.3.6):

- ***Isolation of the gene:*** The gene to be inserted into the genetically modified organism must be chosen and isolated. Most of the genes transferred into plants provide protection against insect or tolerance to herbicide. The gene can be isolated from gene library or artificially synthesised. The gene is then inserted into a bacterial plasmid.

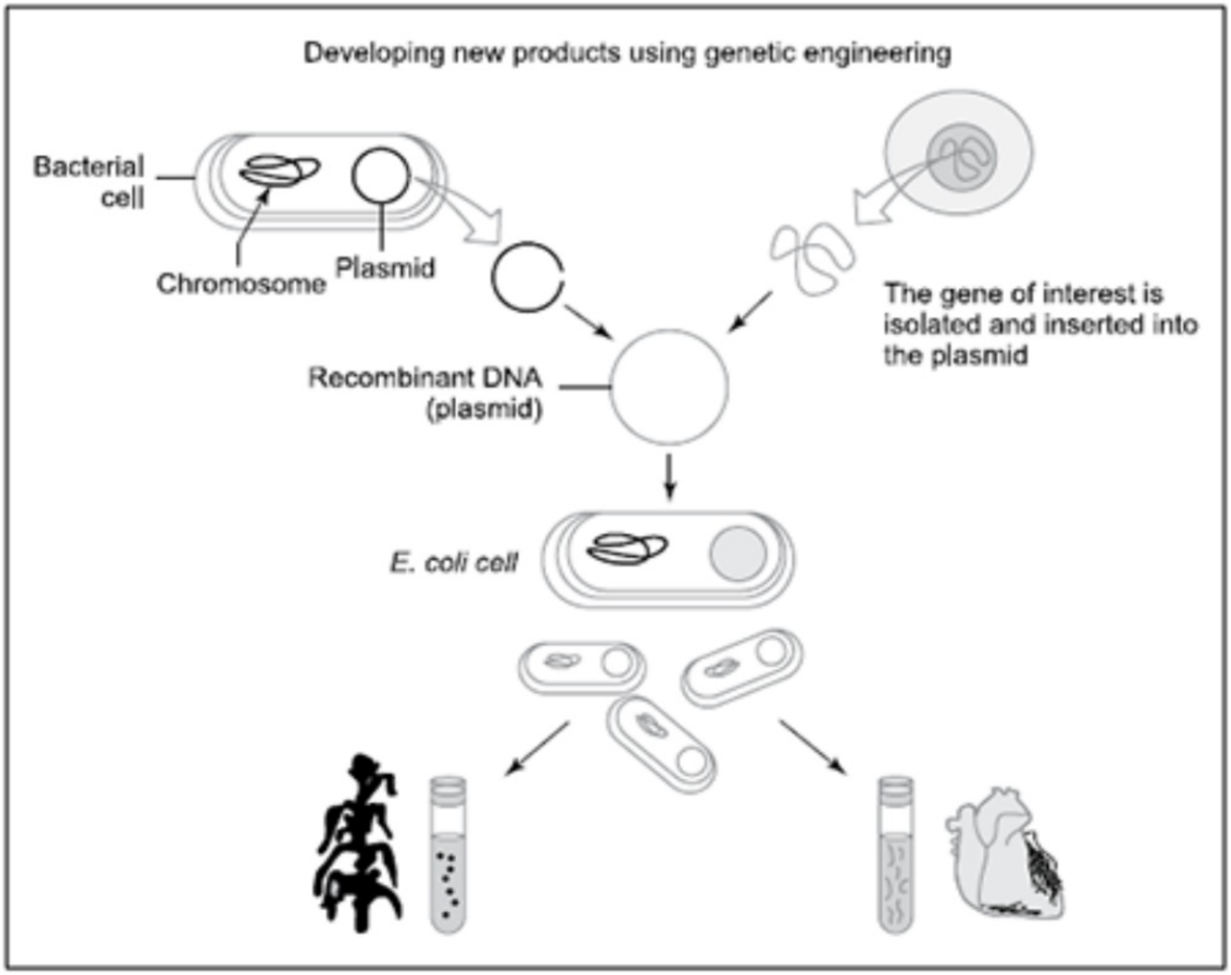

Developing new products using genetic engineering
Bacterial cell
Chromosome
Plasmid
The gene of interest is isolated and inserted into the plasmid
Recombinant DNA (plasmid)
E. coli cell

Figure B.3.6

The basic steps involved in application of genetic engineering.

- ***Cloning Vectors:*** The gene is inserted into other genetic elements for its proper functioning. The gene to be inserted must contain a promoter and terminator region as well as a selectable marker gene. The promoter region initiates transcription of the gene, while the terminator region ends transcription. The selectable marker, antibiotic resistance, helps to determine which cells are transformed with the new gene. The constructs are made using recombinant DNA techniques, such as restriction digest, ligations and molecular cloning.
- ***Gene Targeting:*** The insertion of new genetic material randomly within the host genome. The frequency of gene targeting can be enhanced by the use of engineered nucleases such as zinc finger.
- ***Genetic Transformation:*** DNA is generally inserted into animal cells using microinjection or through the use of viral vectors. In plants the DNA is generally inserted using ***Agrobacterium-mediated recombination*** or ***biolistics.*** *Agrobacterium* naturally inserts DNA (T-DNA) from a tumor inducing (Ti) plasmid into any susceptible plant's genome it infects, causing crown gall disease.

The T-DNA region of this plasmid is responsible for insertion of the DNA. The genes to be inserted are cloned into a binary vector, which contains T-DNA and can be grown in both *E.coli* and *Agrobacterium*. The *Agrobacterium* naturally insert the genetic material into the plant cells. In biolistics, particles of gold or tungsten are coated with DNA and then shot into young plant cells or embryos. Another method for plant and animal cells is *electroporation*; involves subjecting the plant or animal cell to an electric shock, which can make the cell membrane permeable to plasmid DNA.

- ***Selection:*** By growing the cells in the presence of an antibiotic or chemical that selects or marks the cell expressing that gene it is possible to separate the transgenic events from the non-transgenic. DNA probe is also used for screening; it only sticks to the inserted gene.
- ***Regeneration:*** In plants, tissue culture methods are used to regenerate from single transformed cell. In animals, the inserted DNA is present in the embryonic stem cells.

All the offspring from the first generation will be heterozygous for the inserted gene and must be mated together to produce a homozygous animal.

There are other newly developed tools which are used to manipulate DNA.

- ***Gene Knockout:*** It is a technique in which one of the genes in the organism is made inoperative. This techique is used for learning gene function. The difference in normal and knockout individuals tell the role of knockout gene. The first knockout mouse was created by **Mario R Capecch i, Martin Evans** and **Oliver Smithies** in 1989, for which they were awarded the Noble prize for medicine in 2007. A knockout mouse is a genetically engineered one in which inactivated or knockout gene is replaced by artifical piece of DNA. The loss of gene activity causes changes in the mouse. These are important animal models for studing the role of a gene.
- ***Gene silencing:*** Gene silencing involves switching off of the genes by a mechanism other than gene modification. It can be used to inactivate the mRNA transcript of a gene. The mRNA can be blocked by a complementary RNA. The blocking RNA is known as artificial **antisense RNA** and **interference RNA**. Once blocked the single stranded mRNA becomes double stranded. The double stranded RNA does not allow the protein synthesis to take place. The gene has been silenced by blocking the mRNA at transcriptional level. This technique is useful in treating genetic disorders. A defective gene can be stopped to function in an organism.
- ***DNA chips:*** DNA microarrays, gene/DNA chip or biochip, is a technique in which small DNA fragments are attached to a solid surface. The solid surface is made up of glass, plastic or silicon biochip. The main principle behind microarray is hybridisation between attached DNA (target DNA) and known sequence DNA (probe DNA). Where the two DNA (probe and target DNA) bind it shows that particular sequence (probe DNA sequence) is present in the target DNA. Thousand of DNA sequence can be detected simultaneously. This technique is routinely used

for Cancer's gene studies. Another example is the use of DNA chips to test drinking water quality. The microbes (present in water) DNA is isolated and labelled and incubated with the DNA chips. The analysis shows a particular species of microbe is present in the water.

Applications of Biotechnology and Genetic Engineering

Medicine In medicine, biotechnology has promising applications in areas such as:

Drug production: Mouse hybridomas, cells fused together to create **monoclonal antibodies**, have been produced through genetic engineering to create human monoclonal antibodies.

Pharmacogenomics: It is the study of how the genetic inheritance of an individual affects his/her body's response to drugs. It has the following benefits:

- Development of tailor-made medicines. These medicines promise not only to maximise therapeutic effects but also to decrease damage to nearby healthy cells (Table B.3.3).
- More accurate methods of determining drug dosages
- Improvement in the drug discovery and approval process
- Safe and best vaccines

Gene therapy: It can be used for treating, or even curing, genetic and acquired diseases like cancer and AIDS by using normal genes to supplement or replace defective genes. It can be used to target somatic cells or gamete cells. In somatic gene therapy, the genome of the recipient is changed, but this change is not passed along the next generation. In germline gene therapy, the egg and sperm cells of the parents are changed for the purpose of passing on the changes to their offspring. The gene therapy can be done at two levels:

- **Ex vivo:** Cells from the patients blood or bone marrow are removed and grown in the laboratory. They are then exposed to a virus carrying the desired gene. The desired gene then becomes part of the DNA of the cells.
- **In vivo:** Vectors are used to deliver the desired gene to cells in the patient's body.

Table B.3.3

The useful products of Biotechnology

Product	Main use
Insulin	Stimulate glucose uptake from blood in people with insulin dependent diabetes
Erthropoietin	Prevents anemia
Growth hormone	Replaces missing hormones
Factor VIII	Replaces clotting factor
Colony-stimulating factor	Stimulates production of WBC
Platelet-derived growth factor	Stimulates wound healing
Tissue plasminogen activator	Dissolve blood clots
Vaccine proteins: Hepatitis B, herepes, influenza, lyme disease, meningitis, etc.	Prevent and treat infectious diseases

Genetic screening: It involves the direct examination of the DNA molecule. The DNA of patients is screened for mutated sequences. Genetic testing is now used for Carrier screening or the identification of unaffected individual but has one copy for a gene responsible for disease.

Sex determination

Forensic/identity testing (see DNA Fingerprinting Chapter 8)

Newborn Screening

Prenatal diagnostic screening

Presymptomatic testing It is done for estimating the risk of developing and predicting adult-onset disorders such as Hungtington's disease, cancer and Alzheimer's disease. Organisms are genetically engineered to discover the functions of certain genes. These experiments involve loss of function, gain of function, tracking and expression.

Agriculture Many of the genetic characteristics associated with the yield are controlled by a large number of genes, but the current genetic techniques work best for effects that are controlled by a single gene. There are lots of problems which need to be tackled using advancement in the field of biotechnology.

Table B.3.4

Role of biotechnology in agriculture

Problem	Solution
The environmental adaptations of plants	Genes for drought and salt tolerance
Nutritional traits	High-lysine seeds
Post harvest	Delay of fruit ripening
Using plants as bioreactors	Plastics, oils and drugs produced in plants
Crop pest	Herbicide tolerance; resistance to viruses, bacteria, fungi and insects

One of the best known applications of genetic engineering is the creation of genetically modified food. Ethical and safety concerns have been raised for the use of genetically modified crops.

Molecular Genealogy

Molecular genealogy (also called genetic genealogy) is the application of the techniques for characterisation of an individual's DNA to the task of testing a hypothesis that two or more individuals share a common ancestor and of estimating how far back in time that ancestor lived. The Sorenson Molecular Genealogy Foundation (SMGF) is an independent DNA and genealogical research institution with the goal of demonstrating how the peoples of the world are related. SMGF collects DNA samples and genealogical information across the globe to establish these connections. The main aim is to build a database containing over 100,000 DNA samples from individuals all over world.

Model Organisms

A model organism is any species, other than human, that is extensively studied to understand a particular biological phenomena; the discovery made in a model organism provides insight into the working of other organisms. The main characteristic features of model organism are; short life-cycle, easy to

manipulate under experimental conditions and are easily available. There are different model organisms for different groups of living beings. One of the first model systems for molecular biology was *Escherichia coli*, a common bacterium in human digestive system. Some of the important model organisms are: Viruses; Phage lamda, TMV(Tobacco mosaic virus)Prokaryotes;
E.coli, *Bacillus subtilis*, *Mycoplasma genitalium, Pseudomonas florescens Eukaryotes Protists: Chlamydomonas reinhardtii, Dictyostelium discoideum Fungi: Aspergillus nidulans, Saccharomyces cerevisiae Plants: Arabidopsis thaliana, Maize, Lemna gibba Animals: Caenorhabditis elegans, Drosophila, Hydra, Guinea pig, Cat, Mouse (Mus musculus)*

SECTION–II

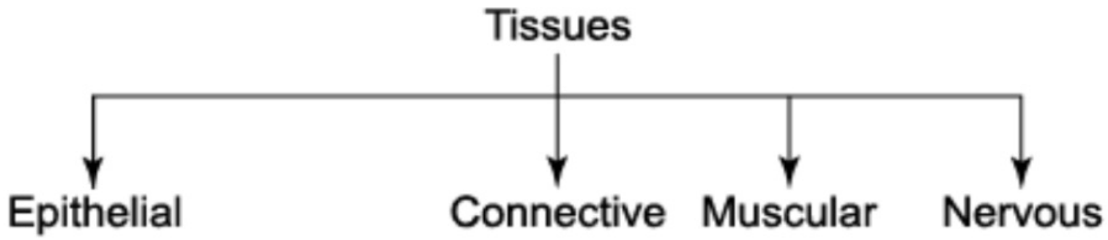
ANIMAL WORLD

CHAPTER FOUR

ANIMAL TISSUES

We learnt about the distinctive features of an animal cell in the previous section. Now, we shall discuss about the **tissues, organs,** and **organ systems**, their structure and function.

Tissues are broadly classified into **four** major types which show **division of labour** in multicellular organisms.



B.4.1 EPITHELIAL TISSUES

Epithelial tissues form sheet of cells that either covers the **external surface** or lines the internal structures. It can be further subdivided into

(i) Simple, which is one-layer thick e.g., epidermis of skin

(ii) Stratified, which have two or more layers e.g., esophagus lining,

(iii) Ciliated e.g., lung alveoli, and

(iv) Pseudostratified contains only a single layer of cells, but it appears to have multiple layers because the cell nuclei lie at different levels and not all cells reach the apical surface, e.g., upper respiratory tract.

Simple and stratified epithelial tissues are also classified on the **basis of shape** into following types:

- **Squamous**—These are thin plate-like cells arranged like tiles on the floor e.g., lining of mouth, nose, blood vessel, etc.
- **Cuboidal**—These cells are cube like e.g., kidney tubules, thyroid vesicles, etc,
- **Columnar**—These are cylindrical in shape e.g., lining of intestine
- **Transitional**—These cells change shape, as organs stretch and relax. e.g., urinary bladder.

  Function: Protection, Transport Secretion, Sensory reception, etc.

B.4.2 CONNECTIVE TISSUE

Connective tissues join and connect part and give support to the body and organs. It is composed of the following three parts:

(a) Cells
(b)Fibres, and
(c) Matrix (ground substance)

The various **types** of connective tissue are:

(i) Areolar (ii) Adipose and **(iii) Reticular connective tissue**

(i) Areolar connective tissue

(a) These are made up of yellow and white fibres and cells, and
(b) These are used as supporting and packing material, passage for blood vessels, and for fastening the skin to muscles.

(ii) Areolar connective tissue

(a) It consists of fat cells, and
(b) It provides insulation, stores body reserves, and functions as shock absorbers.

(iii) Reticular connective tissue (Network)

(a) It is made up of branched fibres
(b) It forms basal framework for number of important organs viz., liver, spleen, tonsils, etc.

In addition to these basic types, bone and cartilage are **supporting** connective tissues, whereas blood is a **fluid** connective tissue.

Bone

It is a specialised connective tissue—**strong** as well as **flexible**. It is made up of three basic components of connective tissue. These are

(i) **Matrix**—It is made of **proteins**, heavily coated with salts of calcium and magnesium viz. **phosphates and carbonates**. Because of presence of mineral salts, bones last long, even after death.

(ii) **Cells**—Bone cells are called **oesteoblasts and osteocytes** ("osteon"—bone, "cytes" cells), which are arranged in the form of concentric **lamellae**, around Haversian canal. These cells are present in fluid filled spaces called **lacunae**. Adjacent lacunae communicate with each other by a network of fine canals, i.e. **canaliculi**.

(iii) **Fibres**—These are collagen fibres.

Function: It gives skeletal support; shape, protection to internal organs and provides anchorage site for muscles, which in turn is responsible for movement.

Cartilage

It is flexible but less vascularised connective tissue than bone. Its structure is more or less similar to bone, with a **matrix** of protein and **cells** suspended in matrix, known as the **chondrocytes** (chondroitin —cartilage, "cytes"—cells). Cartilage cells are present in groups of two or three in lacunae. It is located in flexible parts of the body viz. ear pinna, epiglottis, rings of trachea, etc.

Blood

Blood is composed of **two** basic components (i) **Plasma** (92%)—a fluid matrix and (ii) **Cellular components** (8%).

The **cells** present in the blood are of **three** types:

(a) **Red blood cells (Erythrocytes)** (b) **White blood cells (Leucocytes)** and (c) **Blood platelets (Thrombocytes)**

(a) Red blood cells (Erythrocytes)

(1) These cells contain an iron-containing red-coloured respiratory pigment—the **haemoglobin**.

(2) The cells are circular, biconcave discs **without** nucleus.

(3) **Function**—Transport of nutrients, gases, waste-materials, etc.

(b) White blood cells (Leucocytes)

(1) These are colourless, large, amoeboid cells.

(2) They are broadly divided into (i) **Granulocytes** (cytoplasm with granules) and (ii) **Agranulocytes** (cytoplasm without granules)

(i) Granulocytes: They can be either

- **Neutrophils** (with multilobed nucleus)

    - **Basophils** (with irregular nucleus) or
    - **Acidophils** (with two nuclei joined by a bridge)
  - **(ii) Agranulocytes:** They can be either
    - **Monocytes** (with bean-shaped nucleus) or
    - **Lymphocytes** (with large nucleus almost filling the cytoplasm)

Function—Defense

(c) Blood Platelets (Thrombocytes)

(1) These are very small, fragile fragments of giant cells—the megakaryocytes

Function—Blood clotting

Lymph

It is an **interstitial fluid** drained from tissues, which enters lymphatic system. It's pale yellow in colour, containing lymphocytes and monocytes and is important in the immune system.

B.4.3 MUSCULAR TISSUE

It is of the following three types:

Skeletal or Striated Muscle Fibres

(1) These are known as striped muscle fibres because of presence of alternate light and dark bands.
(2) These fibres are cylindrical in shape.
(3) These are multinucleate and nuclei are peripheral.
(4) They are voluntary (They can be moved at one's own will).
(5) They are attached to the skeleton (hence the name).

Function—Movement, Maintenance of posture, Generation of heat (**thermogenesis**) etc.

Smooth Muscle Fibres

(1) There are no stripes, therefore, they are known as smooth muscle fibres.
(2) These fibres are spindle-shaped, pointed at both the ends.

(3) They bear a single nucleus which is central.

(4) They are involuntary.

(5) They are present in internal organs.
Function—Movement of the internal organs

Cardiac Muscle Fibres

(1) These are also striped muscle fibres.

(2) These are branched fibres.

(3) These appear to be multinucleate with central nuclei, due to presence of "tight junctions".

(4) They are involuntary.

(5) They are present in the heart.
Function—Contraction of the heart

B.4.4 NERVOUS TISSUE OR NEURON

Nervous tissue is made up of three main components:

(1) **Cell body** with a prominent nucleus and deeply stained particles, called **Nissl granules** (ribosomes) and other cellular organelles.

(2) There are many short processes known as **dendrites***,* which receive input or impulse and

(3) A single, long process known as **axon** with fine branches terminally. In myelinated, nerve fibres, axons are lined by a lipid layer known as myelein sheath which is interrupted at certain points known as **Nodes of Ranvier**.

CHAPTER FIVE

BIODIVERSITY: ANIMALS

There is enormous biological diversity!

There are almost 8.7 million species on this earth. This number is rapidly increasing every day. This mind boggling number makes it almost impossible to study each and every organism individually. Therefore, scientists felt that these organisms must be grouped in some fashion into discrete categories. This not only made their job simpler but also helped to characterise them. **This was beginning of a system of classification**. The categorisation however can't be random e.g., if we list names or words in a telephone directory or dictionary randomly, we shall never be able to find or locate a particular telephone number or meaning of a particular word. Therefore, a uniform and universal scientific system of classification was developed for the organisms.

A taxonomist's job didn't get over by merely classifying the organisms; the organisms also needed a scientific name. Since the organisms are known differently at different places and their common names are used casually, it creates confusion, e.g., a silver fish is an insect and not a fish; similarly, sea mouse is not even distantly related with a mouse. Hence, it necessitated a **code of naming** or **nomenclature**.

A number of attempts were made in this direction but success came to the famous Swedish naturalist **Carlus Linnaeus** who developed the system of **Binomial Nomenclature** in his book called **Systema Naturae** in 1758. This distinction earned him the title of "Father of Taxonomy".

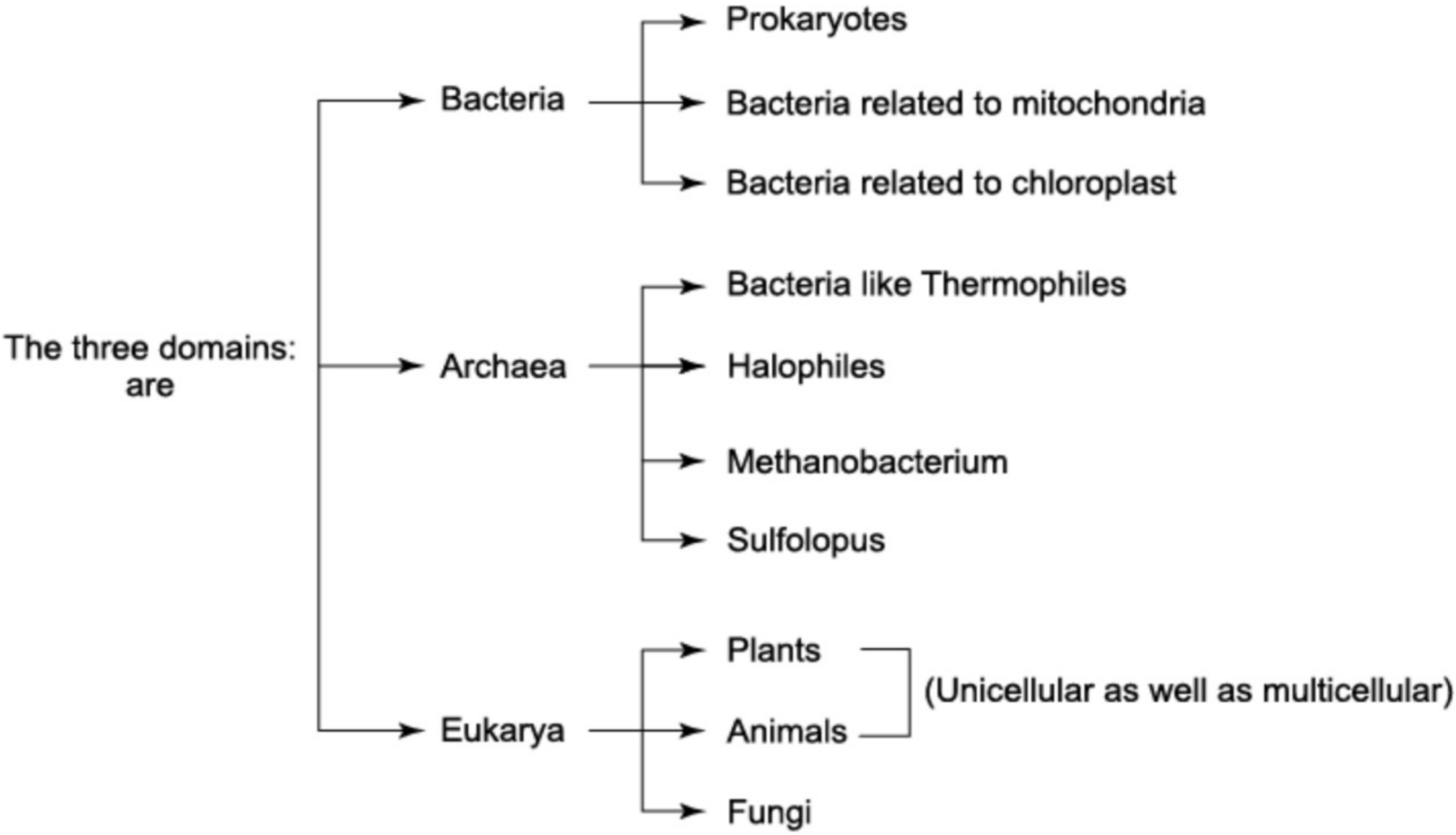
According to his code of nomenclature, ("Bi" meaning "two"), the name of every living organism consists of two words—the **first** word, referring to **generic name** (name of the genus), which is common with other related forms, and the **second** word is **species name** which is unique for a particular organism. The two together specify the name of the species e.g., ***Homo sapiens*** (Man, the wise) is the scientific name of "modern man", where ***Homo*** is the name of the genus and ***sapiens*** is the name of species.

Classification: Classification is possible because there are certain **common features** between related organisms but at the same time, they are also **distinct** from each other e.g., all snakes share certain common features and look more or less similar viz. absence of limbs, body covered with scales, forked tongue, etc. but at the same time a cobra can be easily differentiated from a viper or a krait.

The original system of classification was artificial and based on few characters only. Therefore, it was rejected and since then continuous attempts have been made to improve it and make it more scientific and universally acceptable. This led to the development of the present taxonomic system proposed by **R.H. Whittaker** and known by his name as **Whittaker's Five-kingdom System of Classification** (1969). Here, living organisms are divided into following five kingdoms:

(1) Monera (prokaryotes)
(2) Protista (a diverse kingdom consisting mostly of unicellular organisms both plants and animals)
(3) Plantae (Plants)
(4) Fungi and
(5) Animalia (Animals)

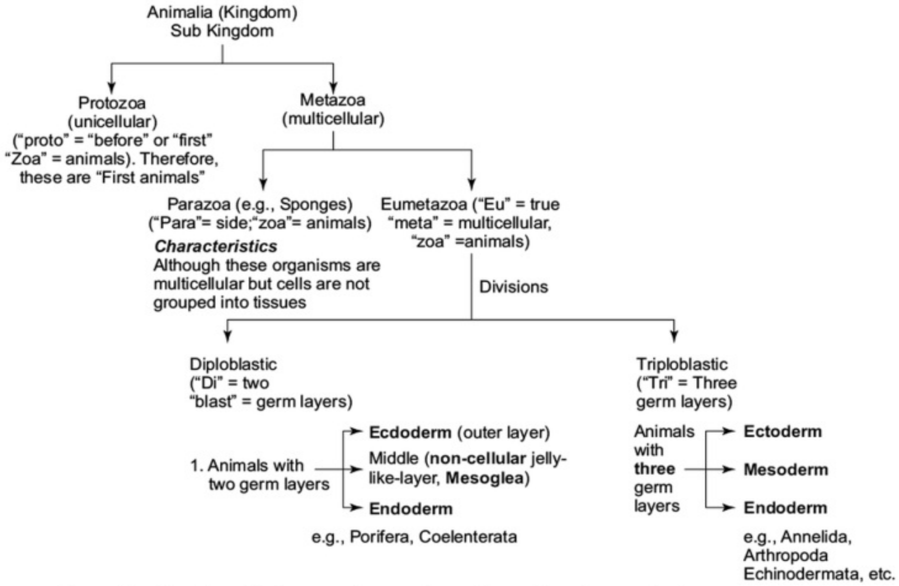
However, when **phylogenies** were worked out on the **basis of genetic data**, it was found that prokaryotes were markedly different not only from eukaryotes but also from each other. This led biologists to modify the present system and adopt a **Three-Domain System**.


The three domains: are
Bacteria
Prokaryotes
Bacteria related to mitochondria
Bacteria related to chloroplast
Archaea
Bacteria like Thermophiles
Halophiles
Methanobacterium
Sulfolopus
Eukarya
Plants
Animals
Fungi
(Unicellular as well as multicellular)

The Domains are a taxonomic level higher than the kingdom level. Currently this system is more popular.

B.5.1 KINGDOM ANIMALIA

The characteristics of animal kingdom are discussed in the following subheadings:


Animalia (Kingdom)
Sub Kingdom
Protozoa
(unicellular)
("proto" = "before" or "first"
"Zoa" = animals). Therefore,
these are "First animals"
Metazoa
(multicellular)
Parazoa (e.g., Sponges)
("Para"= side;"zoa"= animals)
Characteristics
Although these organisms are
multicellular but cells are not
grouped into tissues
Eumetazoa ("Eu" = true
"meta" = multicellular,
"zoa" =animals)
Divisions
Diploblastic
("Di" = two
"blast" = germ layers)
1. Animals with
two germ layers
Ecdoderm (outer layer)
Middle (**non-cellular** jelly-
like-layer, **Mesoglea**)
Endoderm
e.g., Porifera, Coelenterata
Triploblastic
("Tri" = Three
germ layers)
Animals
with
three
germ
layers
Ectoderm
Mesoderm
Endoderm
e.g., Annelida,
Arthropoda
Echinodermata, etc.

These animals are further grouped on the **basis of characters of coelom** (body cavity):

Acoelomate	Pseudocoelomate	Eucoelomate
('A' = absence Coelom = Coelom)	("Pseudo" = False Coelom = Coelom)	("Eu" = True Coelom = Coelom)
1. Body cavity absent	1. Body cavity absent	1. A true body cavity present
2. The space between the body wall & alimentary canal is filled with parenchymatous cells.	2. It is not formed by splitting of mesoderm and not lined by epithelial cells.	2. It is formed by splitting of mesoderm & is lined by epithelial cells
e.g., Protozoa, Porifera Coelenterata Platyhelminthes	e.g., Aschelminthes	e.g., Annelida, Arthropoda Mollusca, Echinodermeta

Animals are also divided into two major groups, on the basis of ***presence or absence of the notochord.***

Non-Chordata	**Chordata***
	(There are 3 main characteristics of chordates)
1. Notochord or Back-bone absent	1. **Notochord** (ventral to nerve cord) present, which is later replaced by cartilage or bone to form vertebral column in higher vertebrates
2. **Nerve cord is Ventral,** if present	2. **Dorsal tubular nerve cord** is present
3. Gill slits absent e.g., From Phylum Protozoa to Echinodermata	3. **Pharynx** is perforated with **gill slits.**

*Phylum Chordata is further subdivided into two groups.

*Chordata groups		
→	**Vertebrata** (Animals with Backbone or vertebral column)	e.g., Pisces (Fishes) Amphibian (Frogs, Toads, etc.) Reptiles (lizards, snakes, etc.) Aves (Birds) & Mammals (Dog, Cat, Monkey, Man, etc.)
→	**Protochordata** (notochord present but vertebral column absent)	

B.5.2 NON-CHORDATA

These animals are so diverse and different from each other that each group has been given the status of a ***Phylum***.

Protozoa (Gr. "Protos"=first; "Zoon"=animals) (or Protista in some system of classification)

These animals are characterised by the following features:

(i) Acellular (These animals are one-celled but ***the cell can act as a complete organism***.)

(ii) Microscopic

(iii) The locomatory structures can be either
- flagella, or
- cilia, or
- Pseudopodia

(iv) Single or living in colonies (colonial)

(v) Free-living or parasitic, present either in freshwater (viz. ponds, lakes, streams, etc.) or marine (sea-water) e.g., *Amoeba, Paramecium, Euglena,* etc.

Porifera ("Pori"=pores; "fera"=bearing)

(i) Pore-bearing animals (body perforated with numerous pores known as ***ostia*****).**

(ii) Multicellular but cells not grouped into tissues or organs.

(iii) Possess a ***water canal system*** for numerous functions of the body viz. bringing in food and oxygen for respiration and removing waste materials and carbon di oxide, etc.

(iv) Skeleton is made up of spicules (made of lime or silica) or spongin fibres.

(v) Sessile or sedentary (attached to the substratum) e.g., *Sycon, Spongilla, Euspongia*.

Coelenterata (modern name Cnidaria) (Gr. "koilos"= hollow; "enteron"=gut)

(i) A gastrovascular or digestive cavity present with a single opening i.e., mouth, hence, the name.
(ii) Special "stinging" cells—"Cnidocytes" present, hence the name Cnidaria.
(iii) The organism shows polymorphism. It can exist in at least two morphological forms—**Polyp** (cylinder like and asexual) and **medusa** (inverted umbrella shaped and sexual), which alternate in the life cycle.
e.g., *Hydra, Obelia, Aurelia* (jelly fish), *Metridium* (sea-anaemone)

Platyhelminthes ("Platy"=flat, plate like; "helminthes"=worms)

(i) ***Flattened*** worm-like body (hence the name) which can be divided into two equal halves (bilateral symmetry).
(ii) The shape of the body is either elongated or tape-like, or ribbon-like.
(iii) Some live in freshwater whereas most of them are parasites.
e.g., *Fasciola* (liver fluke) & *Taenia* (Tape- worm)

Aschelminthes ("ascos"=sac; "helminthes"=worms)

(i) pseudocoelomate
(ii) rounded, worm-like body, pointed at both ends
(iii) Many forms are parasitic in the body of vertebrates
e.g., *Ascaris* (roundworm), *Oxyuris* (pinworm), *Ancylostoma* (hookworm)

Annelida (Latin "Annulus"=ring)

(i) Truly segmented animals. Body is divided externally as well as internally into segments by septa or partitions.
(ii) Truly coelomate
(iii) Locomotory structures either in the form of setae or chaetae (bristle-like structures) or rings.
(iv) Closed blood vascular system (i.e. the blood flows in closed tubes or vessels)
e.g., *Nereis* (clamworm) *Pheretima* (Earthworm), *Hirudinaria* (leech)

Arthropoda (Gr. "Arthro"=jointed; "poda"=foot)

This is a very large phylum and has been elevated to the level of super-phylum by some taxonomists.
(i) Jointed appendages present
(ii) Body covered with hard outer layer ("exo-skeleton") made of chitin
It's further divided into major classes.

(a) Crustacea

(i) Bear ***biramous*** ("bi"=two; "rami"=divided or forked) appendages (i.e. each appendage has two parts)
(ii) Found in water (*aquatic*)—freshwater or seawater.
(iii) Head and thorax fused together to form **Cephalothorax**
e.g., *Palaemon* (Prawn), *Daphnia* (waterflea)

(b) Insecta

(i) Body divided into three parts
- Head
- Thorax &
- Abdomen

(ii) Thorax bears three pairs of legs and two pairs of wings (if insects are winged).

It includes the most familiar and common insects which you see very often in your home, kitchen, garden, etc. Insects are most numerous and highly successful animals e.g., *Musca* (housefly), *Culex* (mosquito), *Periplanta* (cockroach), *Pieris* (butterfly), etc.

(c) Myriapoda ("Myriad"=many; "poda"=foot)

(i) Segmented body with **one or two pairs of legs** present on all the segments except for first and last.
(ii) Air-breathing, present on land
E.g., *Scolopendra* (Centipede—"Centi"= hundred , "pede"=feet)
Julus (Millipede—"Milli"=Million, "Pede"= feet)

(d) Arachnida

(i) Body divided into two parts

(a) Head & Thorax fused together to form **Prosoma**, and
(b) Abdomen (**Opisthosoma**)

(ii) Abdomen with four pairs of legs
e.g., *Aranae* (Spider), *Buthus* (Scorpion)

Mollusca (L., "molluscus"=soft)

(i) Body is soft, unsegmented clothed by a fold of skin known as mantle

(ii) Body divided into
- Head with eyes and tentacles
- visceral mass (internal organs)
- Foot (a ventral muscular organ for locomotion, digging, crawling, etc.)

(iii) Body often covered with shell, secreted by mantle
e.g., *Pila* (apple snail), *Octopus, Lymnaea* (Pond snail), *Sepia* (cuttle fish), etc.

Echinodermata (Gr. "Echino"=Spiny; "Derma"=Skin)

(i) Body surface rough, covered with spines or spicules, therefore, the name.

(ii) Bears a water-vascular system, associated with numerous tube-like structures – the 'tube feet', meant for locomotion.

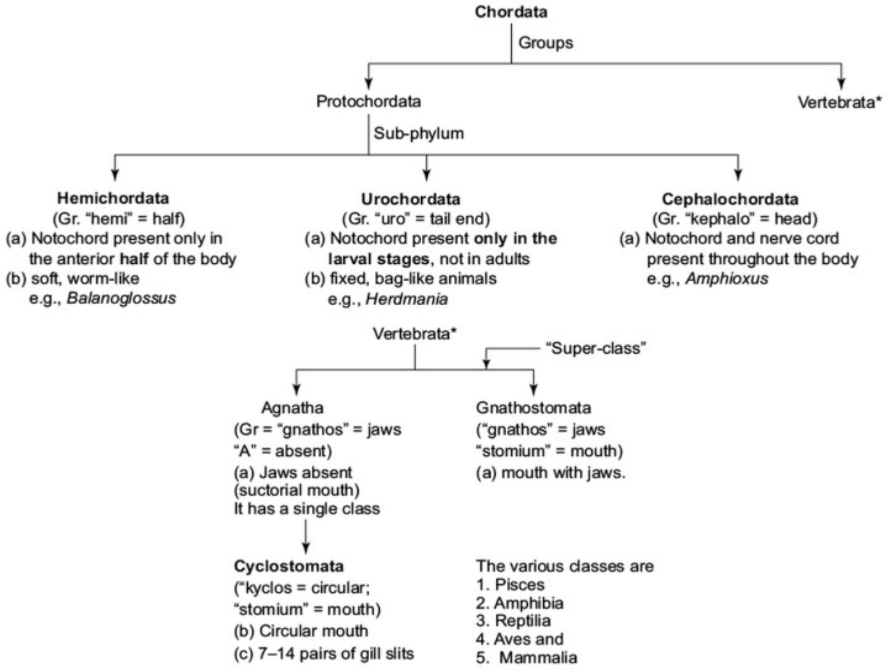
(iii) Symmetry of the body is oriented along five radii—**pentaradial** ("penta"=five; radial=radii)

(iv) Found **only** in sea-water.
e.g., *Astropecten* (Starfish), *Echinus* (sea-urchin), *Antedon* (sea-lily)

B.5.3 CHORDATA

(Gr. "Chorda"=string)

The unique features of chordata have already been discussed.


Chordata
Groups
Protochordata
Vertebrata*
Sub-phylum
Hemichordata
(Gr. "hemi" = half)
(a) Notochord present only in the anterior half of the body
(b) soft, worm-like
e.g., Balanoglossus
Urochordata
(Gr. "uro" = tail end)
(a) Notochord present only in the larval stages, not in adults
(b) fixed, bag-like animals
e.g., Herdmania
Cephalochordata
(Gr. "kephalo" = head)
(a) Notochord and nerve cord present throughout the body
e.g., Amphioxus
Vertebrata*
"Super-class"
Agnatha
(Gr = "gnathos" = jaws
"A" = absent)
(a) Jaws absent
(suctorial mouth)
It has a single class
Gnathostomata
("gnathos" = jaws
"stomium" = mouth)
(a) mouth with jaws.
Cyclostomata
("kyclos = circular;
"stomium" = mouth)
(b) Circular mouth
(c) 7–14 pairs of gill slits
The various classes are
1. Pisces
2. Amphibia
3. Reptilia
4. Aves and
5. Mammalia

Pisces (Series)

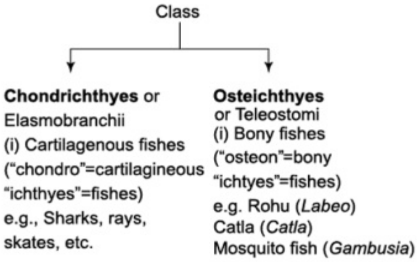
(i) Cold-blooded vertebrates (the body temperature changes with the outside temperature)

(ii) Aquatic (present in water)

(iii) Stream-lined body (to reduce water resistance), covered with scales and provided with fins for swimming

(iv) Gills (respiratory structures meant for breathing in water) present

(v) Commonly known as *Fishes* which can be broadly of two types –


Class
Chondrichthyes or Elasmobranchii
(i) Cartilagenous fishes
("chondro"=cartilagineous "ichthyes"=fishes)
e.g., Sharks, rays, skates, etc.
Osteichthyes or Teleostomi
(i) Bony fishes
("osteon"=bony "ichtyes"=fishes)
e.g. Rohu (*Labeo*)
Catla (*Catla*)
Mosquito fish (*Gambusia*)

Amphibia (Gr.="amphi"=both; "bios"=life)

(i) Cold-blooded vertebrates
(ii) Amphibious—can live both on land and in water
(iii) Moist skin (also used for respiration)
(iv) Tetrapoda ("Tetra"=four; "poda"=feet)— Animals with four limbs.
e.g., *Rana* (Frog), *Bufo* (toad), etc.

Reptilia (Latin, "repre"=to crawl)

(i) Cold-blooded, creeping vertebrates
(ii) Terrestrial (live on *land*), very few live in water
(iii) Skin is dry, scaly, and horny (to conserve water or reduce evaporation)
(iv) Respiration by lungs
e.g., Snakes, lizards, crocodile, etc. Tortoise (*Testudo*)*, Crocodylus* (Crocodile), *Naja* (Cobra).

Aves (L., "avis"=bird)

(i) Warm-blooded vertebrates (Body temperature independent of atmospheric temperature i.e. these animals can **regulate** their body temperature)
(ii) Body covered with feathers
(iii) Fore-limbs modified into wings for **flying in air (aerial)**
(iv) Mouth with **toothless** beak
(v) Commonly known as birds
e.g., *Passer* (Sparrow), *Corvus* (Crow), *Pavo* (Peacock) and *Columba* (Pigeon), etc.

Mammalia (L., "mamma"=breast)

(i) Warm-blooded vertebrates
(ii) Bear "milk" glands or "mammary" glands for nourishing young ones
(iii) Body covered with hair
e.g., Dog (*Canis*), Cat (*Felis*), Bat, Elephant (*Elephas*), Lion (*Panthera leo*), etc.

CHAPTER SIX

ANIMAL FORM AND FUNCTION

B.6.1 NUTRITION

The basic aim of all the living organisms is “to stay alive”. And, for this, they require a steady supply of **food** or **nutrients.**

Biologically, the body needs food and other nutrients mainly for **providing the energy**, which in turn is required for carrying out various cellular activities. However, there are numerous other functions, although minor, which are also served by nutrients.

Living organisms can be classified into following categories on the basis of **modes of nutrition**:

(i) **Autotrophs** (“Auto”= self; “trophe” = nutrition), i.e., self nutrition. It’s a mode of nutrition where an organism synthesises its own food from simple inorganic materials like Co_2 and water (in presence of sunlight) for example, green plants.

(ii) **Heterotrophs** (“Hetero” = others; “trophe” = nutrition). They obtain their food from other organisms. These are **consumers**; e.g, animals. It can be of following types:

  (a) **Saprotrophs** (“Sapro” = rotten). These organisms obtain their food from decaying, organic matter viz. dead plants and animals, e.g., fungi.

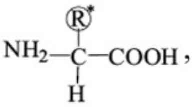
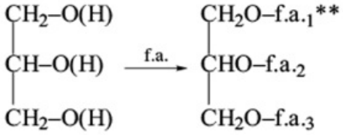
  (b) **Parasites** These organisms derive their nutrition from another living organism, i.e., ‘**host**’.

The animals are heterotrophs. Therefore, they depend upon plants to supply them with already synthesised organic compounds or several other sources to meet their diverse nutritional requirements.

A brief outline of this is given below in the form of a chart (Ref. Table B.6.1 and B.6.2).

Table B.6.1

Nutrients of Food

Organic Nutrient	Source	Functions	Deficiency Diseases
1. Carbohydrates		Source of energy (50%)	
These are hydrates of carbon, the chemical formula is written as $C(H_2O)n$			
(a) Monosaccharides Single sugar (simple sugars with 3 or more carbon atoms)	Glucose, Fructose (grapes) Galactose		
(b) Disaccharides ('Di'=Two) (consist of 2 monosaccharide units)	Maltose (Glucose+Glucose) Sucrose (Glucose+ Fructose) (cane sugar) Lactose–(Glucose+ Galactose) (milk sugar)		
(c) Polysaccharide (many units of monosaccharide (300 to over 1000)	Starch (rice, wheat, potatoes, etc.)		
2. Proteins made up of units called amino acids  $NH_2-\overset{R^*}{\underset{H}{C}}-COOH$, where R* is functional side group	Milk, egg, fish, meat, pulses, soyabean, legumes, etc.	Repair, growth of new cells or tissues, maintenance of structure of the cell	**Kwashiorkor**—edema of the abdomen, enlarged liver, sometimes mental retardation. **Marasmus**—retarded growth, low weight, muscle wasting, dry skin, thin, dry, dull hair.
(a) Essential amino acids These are *not synthesised by* the body but are important for maintenance of the body. These are 20 in number, e.g., Histidine Methionine, Lysine, Leucine, etc.			
(b) Non-essential amino acids These can be synthesised by the body, e.g., Alanino, Aspartic acid Glutamic acid proline, etc.			
3. Fats or Lipids (These are esters of glycerol with fatty acids)  (glycerol) (Triglyceride or fat) **f.a.—fatty acid	Butter, Ghee, Oil, groundnuts, almonds, etc.	Source of energy Insulation, shock absorber	

The energy content of food and wastes is found out by burning them in **bomb calorimeter.**

Table B.6.2

The Vitamins and their characteristics

Name	Important Sources	Functions	Deficiency Diseases
Vitamins "Vit"= "Vital" (essential for life); "amine" = (chemical nature of these components). Hence the name (coined by **J. Funk** in 1912) required in very small amounts, but very important for various functions. If amount is less than the required it results in **deficiency diseases**.			
1. **Lipid-soluble vitamins**			
(a) Vitamin A (**Retinol**)	Plants form carotene in green leaves, carrots, etc; is changed in liver to animal form present in fish-liver oil (shark); both forms in egg yolk, butter, milk	Maintains integrity of epithelial tissues, especially **mucous membrane**; needed as part of **visual purple** in retina of eye	**Xerophthalmia** (dry cornea, no tear secretion), phrynoderma (toad skin) **night blindness**, growth retardation, nutritional croup (hoarseness) in birds
(b)Vitamin D (**Calciferol**)	**Fish-liver oils**, especially tuna, less in cod; beef fat; also exposure of skin to sunlight (ultraviolet radiation)	Regulates **metabolism of calcium** and **phosphorus**; promotes absorption of calcium in intestine; needed for normal growth & mineralisation of bones	**Rickets** in young (bones soft, yielding, often deformed); **osteomalacia** (soft bones), especially in women of Asia
(c) Vitamin E or **Tocopherol** or **anti-sterility** vitamin	**Green leaves, wheat- germ oil** and other vegetable fats, meat, milk	Antioxidative; maintains integrity of membranes	**Sterility in male fowls** and rats, degeneration of testes with failure of spermatogenesis, embryonic growth disturbances, suckling paralysis and muscular dystrophy in young animals
(d) Vitamin K (**clotting vitamin**) anti-hemorrhagic	**Green leaves**, also certain bacteria, such as those of intestinal flora	Essential to production of prothrombin in liver; necessary for blood clotting	**Blood fails to clot**

2. **Water-soluble vitamins**

(a) **Vitamin B complex**

(i) Thiamine (B_1)	**Yeast, germ of cereals** (especially wheat, peanuts, other leguminous seed), roots, egg yolk, liver, lean meat	Needed for carbohydrate metabolism; thiamine pyrophosphate (TPP) an essential **coenzyme** in metabolism	On diet high in polished rice, results in **Beriberi** (nerve inflammation); loss of appetite, with loss of tone and reduced motility in digestive tract; cessation of growth; **polyneuritis** (nerve inflammation)
(ii) Riboflavin (B_2)	**Green leaves**, milk, eggs, liver, yeast	Essential for growth; forms prosthetic group of FAD enzymes	**Cheilosis** (inflammation and cracking at corners of mouth), digestive disturbances
(iii) Nicotinic acid, or niacin	**Green leaves**, wheat germ, egg yolk, meat, liver, yeast	Forms active group of nicotinamide adenine dinucleotide (NAD), which functions in dehydrogenation reactions	**Pellagra** in humans (Symptoms—Tip and lateral margins of tongue, mouth and gums become red, swollen and develop ulcers)
(iv) Folic acid	**Green leaves**, liver, soyabeans, yeast, egg yolk	Essential for growth and **formation of blood cells**	**Anaemia, haemorrhage** in humans
(v) Pyridoxine (B_6)	**Yeast**, cereal grains, meat, eggs, milk, liver	Present in tissues as pyridoxal phosphate which serve as **coenzyme**	**Anaemia**, dermatitis
(vi) Pantothenic acid	**Yeast**, cane molasses, peanuts, egg yolk, milk, liver	Forms coenzyme A	**Dermatitis**
(vii) Biotin (vitamin H)	**Yeast**, cereal grains, cane molasses, egg yolk, liver, vegetables, fresh fruits	Essential for growth; functions in CO_2 fixation	**Dermatitis** with thickening of skin
(viii) Cyanocobalamin (B_{12})	**Liver, fish, meat, milk**, egg yolk, oysters, bacteria and fermentations of **streptomyces; synthesised only by bacteria**	Formation of **blood cells**, growth; **coenzyme**	**Pernicious anaemia**

(b) Vitamin C, or ascorbic acid	**Citrus fruits, tomatoes, vegetables**; also produced by animals (except primates and guinea pigs)	Maintains integrity of capillary walls; involved in formation of "inter-cellular cement"	**Scurvy** (bleeding in mucous membranes, under skin, and into joints)

Physiological Role of Important Minerals

Elements	Source$^{(1)}$	Physiological Role	Deficiency Disease
Potassium (K)	Banana	**Major intracellular positive ion:** nerve and muscle function; acid base balance	**Secondary to illness,** injury or diuretic therapy; paralysis, mental confusion muscular weakness
Calcium (Ca)	Dairy products, beans, leafy vegetables	**Component of bones, teeth;** regulation of nerve, muscle function; blood clotting	Children—**rickets** Adults—**ostomalacia**
Phosphorus (P)	Phosphate food additives	Bone formation, part of DNA, RNA, ATP, etc.; energy metabolism	Children—**rickets** Adults—**ostomalacia**
Magnesium (Mg)	Leafy green vegetables	Bone and teeth; carbohydrate metabolism	Secondary to malabsorption or diarrhea, alcoholism
Chlorine (Cl)	Table salt	Major extracellular negative ion; osmotic and acid-base balance; stomach acid	

Physiological Role of Essential Trace Elements

Element	Source$^{(1)}$	Physiological Role	Deficiency Disease
Iron (Fe)	Iron cookware	Component of haem group in haemoglobins, cytochromes	Anaemia
Copper (Cu)			Anaemia: secondary to malnutrition, Menke's syndrome
Iodine (I)	Iodised salt, Seafood	Component of thyroid hormone	Children: cretinism Adults: goiter, hyper-thyroidism, myxedema
Manganese (Mn)		Needed in urea formation, protein metabolism, glycolysis, citric acid cycle	Unknown in humans
Cobalt (Co)	Foods of animal origin	Constituent of vitamin B_{12}, RBC formation	B_{12} deficiency
Zinc (Zn)		Essential constituent of many enzymes, needed for normal senses of smell and taste	Hypogonadism, growth failure, impaired wound healing, decreased taste and smell

Molybdenum (Mo)		Constituent of some enzymes	Secondary to parenteral nutrition
Fluorine (F)	Drinking water	Hardness of teeth	Dental caries

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[1] Mineral and Trace element requirements are met by a varied intake of whole grain cereal, legumes, leafy green vegetables, meat and dairy products.

B.6.2 DIGESTION AND ABSORPTION

The food (i.e., organic nutrients viz. carbohydrates, proteins and fats) are essentially required for the production of energy. The complete oxidation of food produces energy in the form of ATP (*A*denosine *T*ri *P*hosphate) utilised for various functions. But, naturally, organic nutrients are present in the form of **high molecular weight, complex and large-sized** organic compounds. Therefore, in order to utilise them, they have to be **broken down into low molecular weight, simple and small-sized** molecules. This process in physiology is known as **digestion**. Teeth help in physical digestion whereas enzymes carry out chemical digestion. Digestion is carried out by various kinds of enzymes and acids (see Table B.6.3).

However, digestion without **absorption** is incomplete, because the digested nutrients have to ultimately reach the cells or tissues, which will oxidise them for their energy requirements. Hence, the digested nutrients must cross the cell barrier, enter the blood stream, and reach their final destination, the cells or tissues. This process is called as **absorption**. **Thus, digestion and absorption are inter-related**. In simple organisms, food is captured or engulfed either by pseudopodia, cilia or flagella. This is known as **phagocytosis** (“phago” = feeding; “cyto” = cell). The phagocytosed food forms a **food vacuole.** The enzymes inside the food vacuole digest it and digested food is then absorbed by diffusion. In higher organisms, however, the process is complicated.

A summary of various digestive processes operating in the alimentary canal of humans is given in the table.

Table B.6.3

Region of digestion	Name of the secretion	Enzymes or Secretion	Substrate	Optimal pH	Products formed
***Mouth:* oral digestion** Salivary glands	Saliva	Salivary amylase	Starch	6.8	Maltose (disaccharide) via dextrins
***Stomach:* Gastric digestion** (a) Gastric glands	Gastric juice				
(i) Chief cells		(a) Pepsinogen (inactive) + HCl Æ Pepsin (active)	Protein	1.5 to 2.0	Peptones via acid meta-

					proteins and proteoses
		(b)Prorennin (inactive) + H^+ Æ Rennin (active)	Milk protein caseinogen		“Curdling” of milk
		(c) Gastric lipase	Fats/Lipids		Fatty acids & mono glycerides
(ii) Parietal cells		(a) HCl	Pepsinogen		(a) converts pepsinogen (inactive) to pepsin (active)
		(b) Intrinsic factor			(b) For absorption of vitamin B_{12}
(iii) Mucous cells		(c) Mucus			(c) Protection of under-lying layers & lubrication of food
(iv) G-cells		(d) Gastrin (a hormone)			(d) It stimulates parietal cells to secrete HCl
3.*Intestine*: **Intestinal digestion**					
(a) **Pancreas** (pancreatic acini in exocrine part of pancreas)	1. Pancreatic juice	*Protein splitting* (a) **Trypsin**: Trypsinogen (inactive) + enterokinase from duodenal mucosaÆ Trypsin	Protein	8.0	Polypeptides via metaproteins, proteoses and peptones
		(b) **Chymotrypsin:** Chymotrypsinogen (*inactive*) + trypsin Æ Chymotrypsin		do	amino acids
		(c) **Carboxypeptidase**	Terminal amino acids at carboxy end		
		(d) **Elastase**	Polypeptide		
		(e) **Pancreatic amylase** (amylopsin)	Starch (carbohydrate splitting)	8.0	Maltose (disaccharide) via dextrins Maltotriose (trisaccharide)

		(f) **Nucleases**			
		(i) Deoxyribonuclease	DNA	do	Nucleotides
		(ii) Ribonuclease	RNA	do	Nucleotides
		(g) Pancreatic Lipase (Fat splitting)	Fat	do	Fatty acids + glycerol
(b) **Liver**	Bile	No enzyme; Instead contains **bile salts** which activate Lipases & emulsify fats		7.1 to 7.3	
(c) **Small Intestine** (Brush Border cells of intestinal glands)	Intestinal juice (**succus entericus**)	*Protein splitting* (a) **Aminopeptidase**	Polypeptides and short peptides (a) Terminal aminoacids at amino end	8.0	Amino acids Peptide fragments
		(b)**Dipeptidase**	(b) Dipeptides		
		(c)**Tripeptidase**	(c) Tripeptides		
		(d) **Maltase** (Carbo-hydrate splitting)	Maltose	do	Glucose + glucose
		(e) **Lactase**	Lactose	do	Glucose + galactose
		(f) **Sucrase**	Sucrose	do	Glucose + fructose
		(g) **Lipase**	Fat	do	Fatty acids + glycerol
		(h) **Nucleosidases & Phosphatases**	Nucleotides	do	Nitrogenous bases, pentoses & phosphate
		(i) **Enterokinase**	Trypsinogen	do	Trypsin

Motility

When the food enters the alimentary canal, it has to be moved forward in a regulated manner from the mouth to anus, so that, it can be properly digested and absorbed. These movements are performed by the smooth muscle fibres lining the alimentary tract. Their contractions bring about what is known as **motility** of the gastro-intestinal tract. Two basic types of movements occur: (1) **Mixing movements** which keep the juices thoroughly mixed with the food and (2) **Propulsive movements** which move the food forward along the tract at an appropriate rate for digestion and absorption. These movements are popularly known as *peristaltic contractions* or

peristalsis.

Absorption

Major amount of food i.e. more than 90% of digested food and about 10% of water and minerals are absorbed in the small intestine. It is provided with a number of special finger-like structures, known as **villi**. These villi along with smaller divisions, the, **microvilli** (about 1000 microvilli per villus) help to **increase the surface area** for absorption. Carbohydrates and proteins are absorbed in blood capillary network (artery and vein) whereas **fats or lipids are absorbed in blind-ended lymphatic vessels** called as **lacteals**.

Egestion

A part of the food is not digested or absorbed by the small intestine. This undigested food moves to the last part of the alimentary canal, the **large intestine**. The walls of the large intestine absorb water, sodium ions and some vitamins from the food. Therefore, the undigested food—the **faecal matter,** becomes semi-solid and enters into rectum, where it's stored for some time and finally expelled out through anus. This act is known as **defecation** which is caused by the contraction of the rectum and relaxation of anal sphincter.

Clinical Disorders of the Digestive System

(1) *Vomitting*—When the contents of upper GI tract (stomach and sometimes duodenum) are thrown out forcibly through the mouth; due to certain irritants viz. unpleasant sights or irritation of the stomach, etc., it is known as *vomiting*.

(2) *Diarrhoea*—Infectious disease of the GI tract resulting in loose, frequent bowel movements and dehydration (loss of water). It occurs because of contaminated food or water by bacteria (particularly *E. coli*), viruses or protozoan parasites.

(3) *Jaundice* is yellowish colouration of skin and mucous membrane due to buildup of bile pigment, **bilirubin** from the liver.

(4) *Gall stones*—If bile contains insufficient bile salts or excessive cholesterol, the cholesterol crystallises in the form of gall stones.

(5) *Appendicitis*—is inflammation of the appendix.

(6) *Constipation*—There is difficulty in defecation because of decreased motility (movement or contractions) of large intestine. The feces become dry and hard because of excessive water absorption. When there is excess strain in defecation, it forces blood into the rectal veins, also called as *piles*.

(7) *Ulcers* are lesions or wounds in the membrane of GI tract exposed to acidic gastric juice.

(8) *Hepatitis* is an inflammation of the liver caused by viruses, drugs, chemicals and alcohol.

(9) *Hernia*—Protrusion of all or part of an organ through a membrane or cavity wall, usually

the abdominal cavity.

B.6.3 RESPIRATION AND GAS EXCHANGE

Respiration is an important **visible sign of life**. Chemically, this process of complete oxidation of the organic nutrients to produce energy in the form of ATP—the "energy currency of the cell", is known as **respiration**. However the **mechanical process,** which comprises **both of inhalation** or inspiration and **exhalation** or expiration, is called as **breathing**.

Respiration can also be **aerobic,** i.e., (respiration in the presence of oxygen) or **anaerobic** (without oxygen) or fermentation (e.g., prokaryotes). It's carried out with the help of various structures. Some of them are listed as follows:

Respiratory structures in different animals

Man, Birds and lizards, etc.—Lungs (alveoli)
Frogs and Toads—Lungs and moist skin
Fish and other aquatic organisms—gills
Insects—Tracheal network (branches of "air-tubes")
Scorpions—Book Lungs
Earthworm—moist skin
Amoeba, Planaria—Simple diffusion through cell membrane. As they are very small and thin-walled, gases can directly diffuse.

Structure

The main respiratory structures in man are paired, lobed, highly spongy and elastic organs—the **lungs**. These are located in the chest cavity. Each lung in turn is made up of millions of tiny, balloon or grape-like blind sacs, known as **alveoli**. These alveoli are very thin walled and richly supplied with blood vessels. These are the **actual site of gas exchange**. But air or oxygen from the atmosphere cannot reach these alveoli directly. It has to pass through the **conducting system** of air-tubes (Nostrils → Nasal cavity → larynx → trachea (wind-pipe) → bronchi → bronchioles). These air-tubes are highly divided and branched into finer tubes, which carry the oxygen to the alveoli of lungs and carbon-dioxide in the reverse direction.

Mechanism

Breathing is brought about by alternate contraction and relaxation of dome-shaped structure, known as **diaphragm** and external **intex costal muscles** inserted on ribs. These two together expand the thoracic cavity by flattening the diaphragm and moving the sterna and rib cage outwards and upwards, during inspiration. Since, this causes an increase in the volume of thoracic cavity, the atmospheric air rushes in, due to difference in pressure between outside and inside. The process is reversed during expiration.

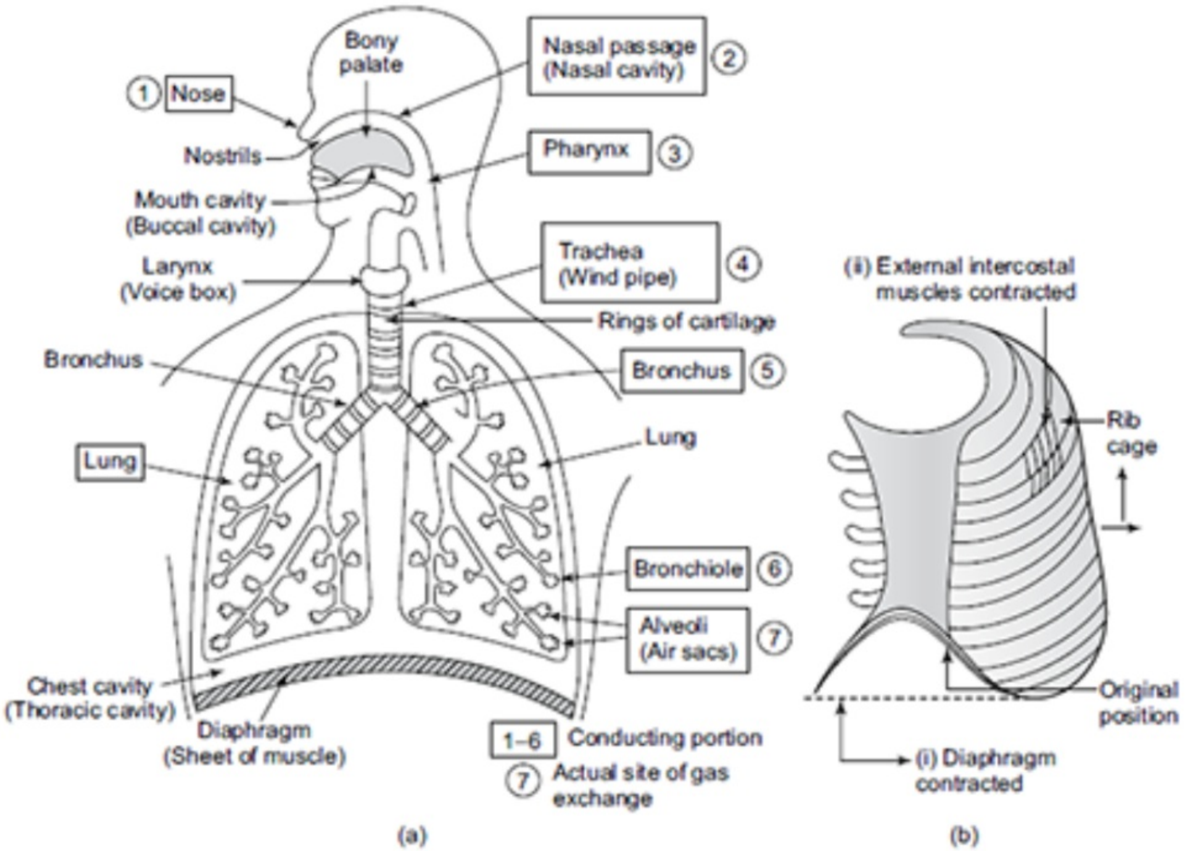
Once the atmospheric air reaches the alveoli, the exchange of respiratory gases (O_2 & CO_2) occurs by simple **diffusion**. The membrane separating the alveoli from blood capillaries is extremely thin (0.1u) and the inspired air is rich in oxygen. The partial pressure of O_2 (PO_2) in inspired air is 100 mmHg, therefore, oxygen diffuses from alveoli (high PO_2) to blood vessels with low partial pressure (40 mmHg). The blood has low PO_2, because it is returning from the cells or tissues undergoing metabolism. Hence, it's rich in carbondioxide and low in oxygen.

Transport

On reaching the blood vessels, major amount of respiratory gases, particularly oxygen, is transported in combination with the iron-rich respiratory pigment **hemoglobin**. Some amount however, is also transported in the **soluble form.** Carbondioxide, however is transported in the form of **bicarbonate ions**.

Cellular Respiration

The blood carries the respiratory gases to their final destination, the, cells or tissues. Here, oxygen is utilised for metabolic purposes involving oxidation of organic food, by a series of biochemical reactions. These metabolic reactions finally produce carbon dioxide, water and energy in the form of ATP, e.g, a single molecule of glucose is metabolised by **Glycolysis, Kreb's cycle** and then by **Electron Transport Chain** in mitochondria aerobically to yield 36 molecules of ATP. Similarly amino acids and fatty acids are also oxidised along their biochemical pathways to produce energy. This is known as **cellular respiration**. Carbondioxide, generated as a by product in these reactions is then eliminated by expiration.


Bony palate
① Nose
Nasal passage (Nasal cavity) ②
Nostrils
Pharynx ③
Mouth cavity (Buccal cavity)
Larynx (Voice box)
Trachea (Wind pipe) ④
Rings of cartilage
Bronchus
Bronchus ⑤
Lung
Lung
Bronchiole ⑥
Alveoli (Air sacs) ⑦
Chest cavity (Thoracic cavity)
Diaphragm (Sheet of muscle)
1–6 Conducting portion
⑦ Actual site of gas exchange
(ii) External intercostal muscles contracted
Rib cage
Original position
(i) Diaphragm contracted

(a) (b)

Figure B.6.1

The human respiratory system

Lung-Function Test or **Pulmonary-Function Test (PFT)** is carried out to measure volumes and capacity of lungs. It is measured using an instrument known as **spirometer**.

Clinical disorders of Respiratory System

(1) *Coryza and Influenza or flu* (Common cold)—Hundreds of viruses can cause coryza or common cold but *rhinoviruses* group is responsible for about 40% of all colds. Typical symptoms are sneezing, excess nasal secretion, cough and congestion.

(2) *Asthma*—It is a disorder caused by inflammation or hypersensitivity to a variety of stimuli and obstruction of air-way, resulting in difficulty in breathing, coughing, wheezing, etc.

(3) *Pneumonia*—acute infection or inflammation of alveoli by the bacterium, *Streptococcus phenumoniae*. Symptoms are fever, chills, productive or dry cough, chest pain, difficulty in breathing and in severe cases spitting of blood.

(4) *Tuberculosis*—is inflammation of lungs and the pleural membrane primarily, (but sometimes other parts of the body may also be involved) by the bacterium. *Mycobacterium tuberculosis*—It is an infectious and communicable disease. The

symptoms are fatigue, weight loss, lethargy, low-grade fever, cough, difficulty in breathing and spitting of blood in advanced stage of disease.

(5) *Emphysema* is a disorder where the walls of the alveoli are destroyed, producing large air space and less surface area for gas exchange. It is generally caused by cigarette smoke, air and industrial pollution. The patient becomes breathless and the chest size increases.

All eukaryotes show aerobic respiration, carried out by ***mitochondria*** except some unicellular organisms viz. yeast.

B.6.4 THE CIRCULATION AND THE TRANSPORT SYSTEM

The food which enters through the mouth is digested mainly in the intestine and oxygen which enters through nose is present in lungs. Both are far away from the site of the activity i.e. cell or tissue. Therefore, it needs to be **carried to** or transported to its final destination. At the same time, waste products and carbondioxide have to be **carried away** from the cells or tissues and removed from the body, as they are poisonous and harmful. Both these functions are performed by the **Blood Vascular System** which acts as the circulating medium in humans. The circulatory system has two major components—a pulsatile pump (**the heart**) and a system of tubes or channels (**the blood vessels**).

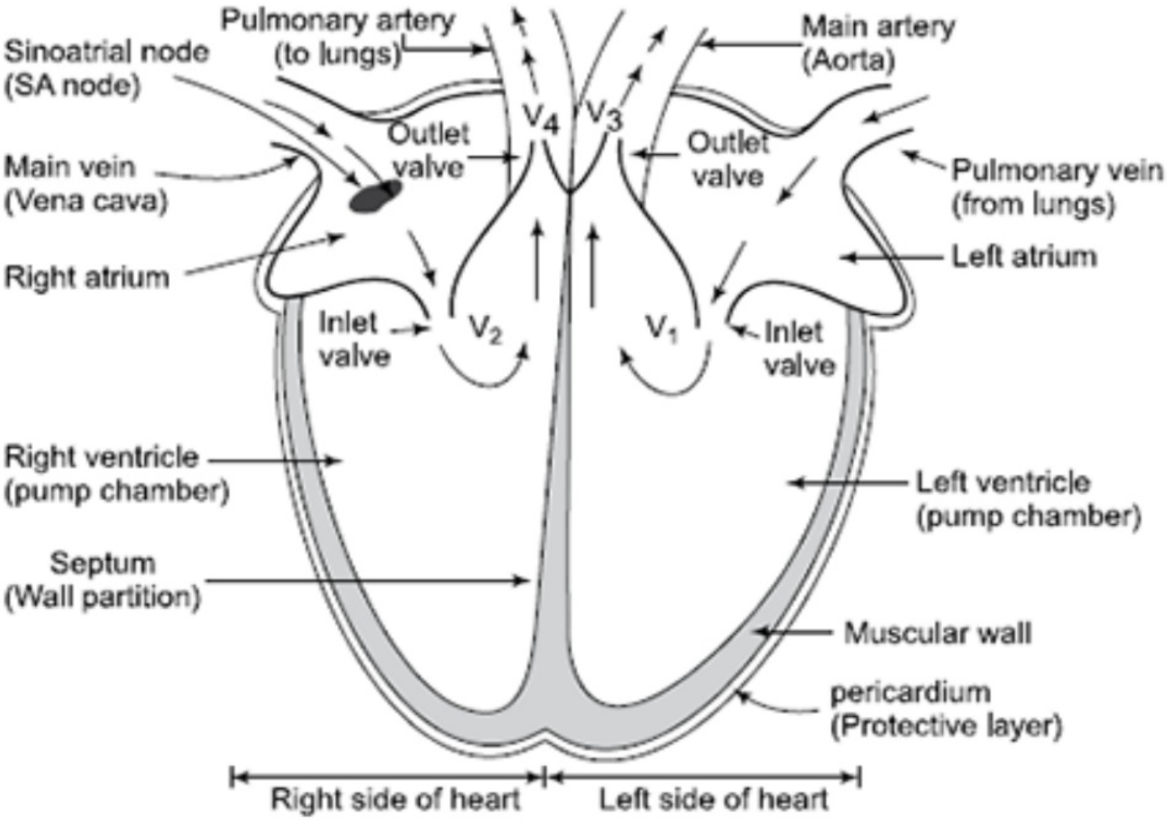

Pulmonary artery
(to lungs)
Sinoatrial node
(SA node)
Main artery
(Aorta)
V_4
V_3
Outlet
valve
Outlet
valve
Main vein
(Vena cava)
Pulmonary vein
(from lungs)
Right atrium
Left atrium
Inlet
valve
V_2
V_1
Inlet
valve
Right ventricle
(pump chamber)
Left ventricle
(pump chamber)
Septum
(Wall partition)
Muscular wall
pericardium
(Protective layer)
Right side of heart
Left side of heart

Figure B.6.2

Inside structure of a Human Heart

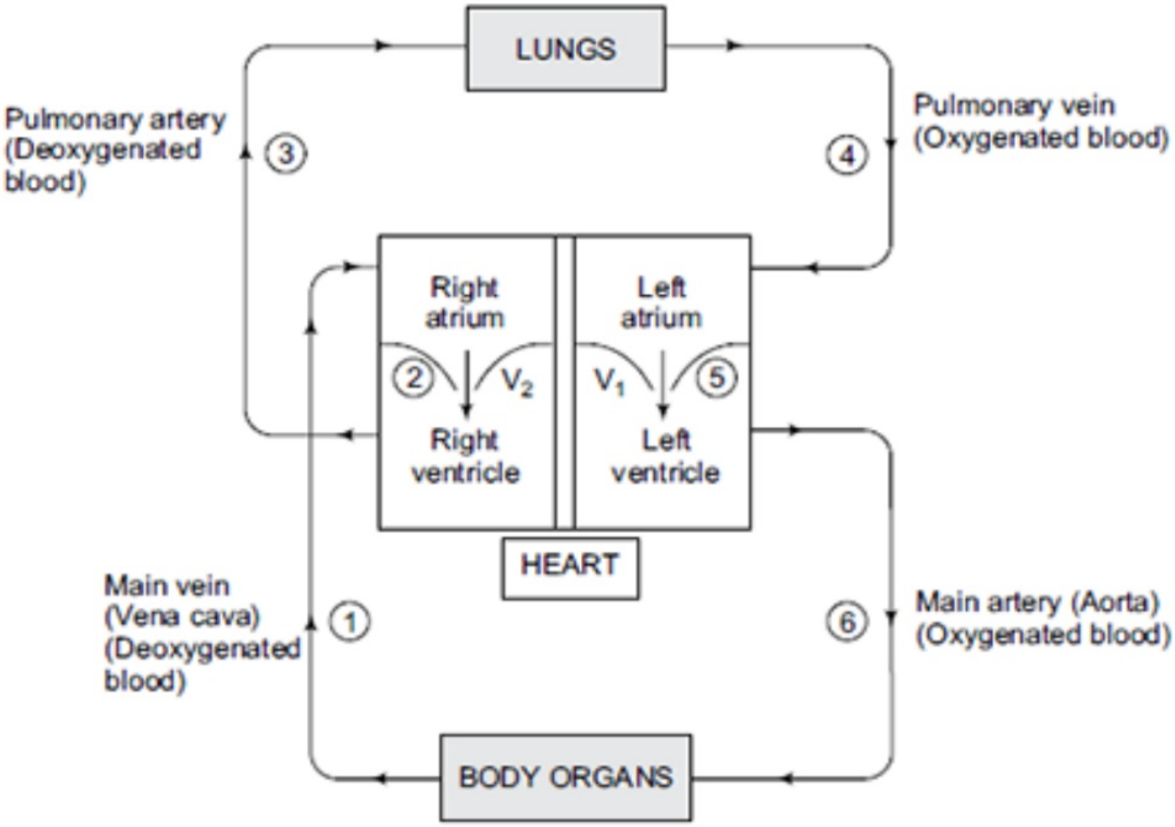

LUNGS
Pulmonary artery (Deoxygenated blood)
③
④
Pulmonary vein (Oxygenated blood)
Right atrium
Left atrium
②
V2
V1
⑤
Right ventricle
Left ventricle
HEART
Main vein (Vena cava) (Deoxygenated blood)
①
⑥
Main artery (Aorta) (Oxygenated blood)
BODY ORGANS

Figure B.6.3

Diagram to show blood circulation in human body

Structure

Heart is a four-chambered organ made up of two **upper chambers—right and left atria and two lower chambers—right and left ventricles**. The two atria and ventricles are separated from each other by a partition—the **inter-atrial septum** or **inter-ventricular septum,** respectively. However, the atrium and ventricle of either side communicate with each other through valves. The right atrium and ventricle are connected through **tricuspid valve** ("Tri" means 'three') with three flaps or cusps and left chambers are joined through **bicuspid valve** with two flaps or cusps.

The Course of Blood Circulation

The blood flows through the heart in the following manner:

The deoxygenated blood reaches the **heart** through two major veins—(a) the **superior venacava** and (b) the **inferior venacava**. The s**uperior venacava** brings back "impure" or deoxygenated blood from cells or tissues of the **upper** part of the body and the **inferior venacava** brings deoxygenated blood from cells or tissues of the **lower** part of the body. Both drain this blood into the **right atrium** of the heart. The blood from the right atrium then enters into the **right ventricle**, through **tricuspid valve**. It then goes to **lungs** through **pulmonary arteries** for oxygenation. The oxygenated blood then re-enters the heart at the left atrium through **pulmonary veins.** From left atrium it goes to **left ventricle**, through **bicuspid or mitral valve**. It finally comes out of the heart, through **aorta** and its branches, which supply this oxygenated blood to the rest of the body.

> The heart supplies blood to all parts of the body, but it in turn is supplied by the **coronary arteries and veins**, a branch of aorta.

Origin and Conduction of Heart Beat

In man, heart is a pulsatile, four-chambered, roughly triangular, highly muscular organ which contracts rhythmically to push the blood through a network of blood vessels. The contraction of the heart, which is commonly known as "**heart beat**", begins by an **automatic, inbuilt** excitation or stimulation of a region located in the upper right chamber, or "right atrium". This region is known as **sinoatrial node** (SA node). (Please refer to the diagram). The heartbeat, which is initiated at SA node, is an **electrical signal** and it spreads from its origin to other regions of the heart, resulting in its contraction as a whole. This is a rhythmical phenomenon and therefore, the pulsatile rate of a normal adult heart beat is **72 beats per minute**. The sinoatrial node, where the heart beat begins is, also called as the **normal "pace-maker"** of the heart, because it sets the rhythm of the heart beat. If the heart beat originates at a site other than the normal pacemaker of the heart, it is known as **ectopic focus**.

Heart Sounds

The opening of the "valves" do not produce any sound because it is a slow process but **closing of the valves** produces sound, known as "**heart sounds**". These sounds are recorded by a special instrument known as **stethoscope**. These are of two types (1) **"lubb"** and (2) **"dupp"**. (1) "**Lubb**" (first heart sound)—It is of **low** amplitude, **lasts longer** and is caused by closure of valves between atria and ventricles. (2) "**Dupp**" (second heart sound)—It is of **high** amplitude, of **short duration**, and is caused by closure of aortic and pulmonary valves.

The recording of heart sounds is referred to as "phonocardiograph".

> **ECG** (Electro Cardio Graph)—refers to the recording of the electrical activity of the heart. It can be (a) resting ECG or (b) stress ECG (also known as Tread Mill Test or TMT).

Blood Pressure

The force or pressure, which the blood exerts against the walls of the blood vessels, while flowing through it, in common language, is known as blood pressure. However, the scientific term for this is **arterial pressure,** i.e., the pressure in the arteries. It has two components: (a) Systolic pressure and (b) Diastolic pressure.

(a) **Systolic pressure** (higher)—it is the pressure exerted when the ventricle **contracts and ejects** the blood, which causes a **rise** in the pressure.

(b) **Diastolic pressure** (lower)—it is the pressure exerted when the ventricles **relax and get filled** with the blood. This results in **fall** in pressure.

Both these pressures need to be recorded by a doctor. This is done using a pressure measuring device, called as **sphygmomanometer**.

For a normal young adult, this pressure is 120/80 (systolic pressure/diastolic pressure). It increases with age (140/90 mmHg), because the blood vessels become inflexible or less stretchable as well as narrow with the age. Therefore, the blood has to exert more pressure in order to flow. This is medically known as **hypertension,** or more familiarly as **high blood pressure**. The blood pressure rises with stress or tension.

Artificial Pacemaker

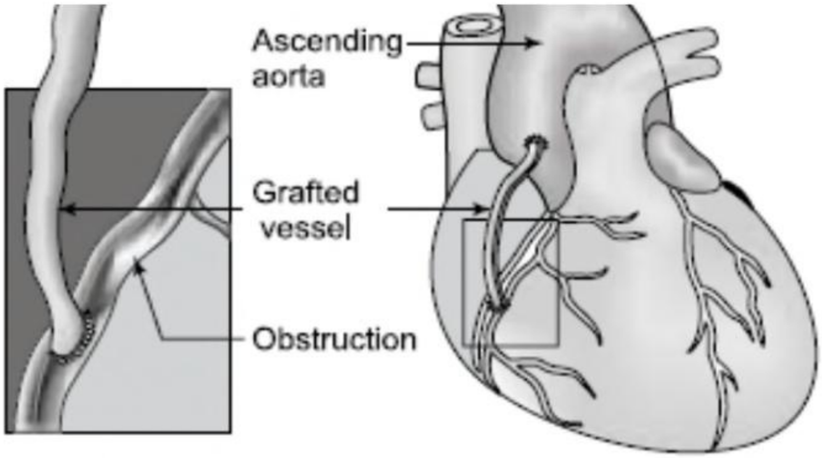
If the normal pacemaker of the heart, i.e., sinoatrial node becomes damaged or diseased and the pacing rate becomes very slow (only 20–35 beats per minute), the blood flow to the brain becomes insufficient. Under such conditions, normal heart rhythm can be restored and maintained by surgically implanting an artificial device. This sends out small electrical currents to stimulate the heart to contract, known as **artificial pacemaker**.

Heart Transplant—In 1967, a human heart was transplanted by Dr. Christian Bernard in Cape Town (South Africa).

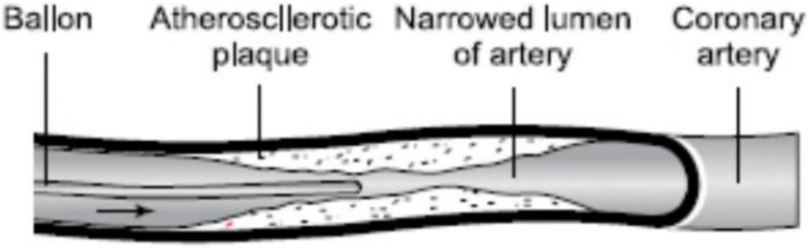
First permanent mechanical heart/artificial heart, designed by Dr. Robert Jarvik, was implanted in 1982. It was developed to perform the function of live tissues.

Clinical Disorders of Circulatory System

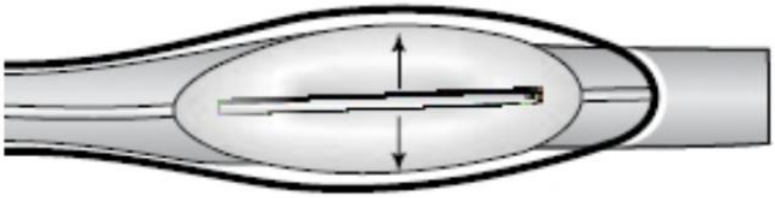
(1) *Anemia*—All types of anemia are characterised by reduced number of RBCs or decreased amount of hemoglobin in the blood. The symptoms are fatigue, pale skin, intolerance to cold. There can be various types of anemia, viz.
    (a) Iron = deficiency anemia (deficiency of iron)
    (b) *Pernicious anemia* (deficiency of vitamin B12)
    (c) Hemolytic anemia (plasma membrane ruptures)
    (d) Aplastic anemia
    (e) Sickle cell anemia is a *genetic* disorder where RBCs become sickle-shaped
    (f) *Thalassemia*—a group of **hereditary**anemias. RBCs are small, pale and short lived.


Ascending aorta
Grafted vessel
Obstruction

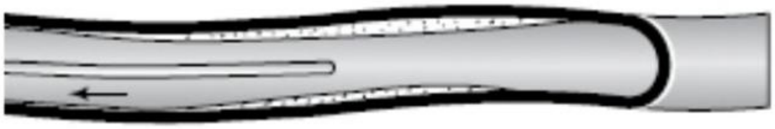
(a) Coronary artery *bypass* grafting (CABG)


Ballon
Atheroscllerotic plaque
Narrowed lumen of artery
Coronary artery

Ballon catheter with uninflated balloon is threaded to obstructed area in artery

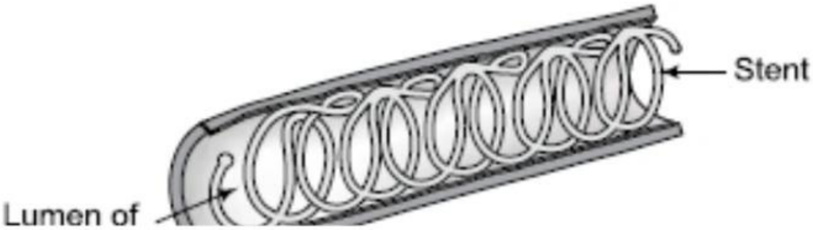


When balloon is inflated, it stretches arterial wall and squashes atherosclerotic plaque



After lumen is widened, balloon is deflated and catheter is withdrawn

(b) Percutaneous transluminal coronary *angioplasty* (PTCA)


Stent
Lumen of

(c) *Stent* in an artery

Figure B.6.4

Three procedures for reestablishing blood flow in occluded coronary arteries

(2) *Hemophilia*—ahereditarydiseaseinwhich there is failure of blood clotting (due to absence of certain clotting factors) leading to spontaneous or excessive bleeding.

(3) *Leukemia*—is a type of cancer (malignant disease) characterised by uncontrolled production of leucocytes (WBCs).

(4) *Arteriosclerosis—Hardening* of the arteries due to thickening of the walls of arteries or loss of elasticity.

(5) *Atherosclerosis*—is characterised by deposition of *plaques* (glossary) in the walls of the arteries, resulting in narrowing or obstruction of arteries.

(6) *Varicose veins*—The veins of the legs appear as swollen, blue veins because of loss of elasticity.

(7) *Angina pectoris* literally means "strangled chest" is a severe pain in chest muscles or below collar bone due to reduced oxygen supply (*hypoxia*) or reduced blood flow (*ischemia*) to heart muscles.

(8) *Myocardial infarction* (MI) or commonly called as *heart attack*. Infarction means *death* of an area or tissue due to reduced blood supply. The heart tissue dies because of insufficient blood (oxygen) supply, due to complete obstruction of coronary artery (*coronary thrombosis*). The typical symptoms are crushing pain in the chest, neck, chin radiating to the left arm, accompanied by excessive sweating and shortness of breath.

(9) *Tachycardia* ("Tachy" = fast; "Cardia" = heart): An abnormally rapid heartbeat or pulse rate (>100 beats/min)

(10) *Bradycardia*—slower heart rate (than normal) < 60–70 beats/min

B.6.5 EXCRETION

Metabolism involves two major processes—(i) synthesis of compounds, known as **anabolism** or (ii) breakdown of compounds called as **catabolism**. In a biological system, breakdown of compounds produces products which are either utilised by the body for various purposes or consumed in a reaction or removed from the body. The breakdown of proteins, in particular and other nitrogenous compounds, which are not utilised by the body for repair, growth or synthesis, produce the so called "**waste materials**". These waste materials are actually the **breakdown products of proteins** forming various kinds of nitrogenous compounds viz. urea, ammonia, uric acid and creatinine. These are called as **nitrogenous waste products**. They cannot remain in the body for long because they are highly toxic and therefore must be removed from the body. This process of removal of nitrogenous wastes from the body is known as **excretion**. Further, the removal of these wastes requires water. The amount of water required varies with the type of nitrogenous compound excreted, e.g., removal of ammonia requires lot of water. Therefore, organisms living in water, or **aquatic** organisms produce this as a waste product and are known as **ammonotelic organisms**. The animals living on land, the **terrestrial animals** who need to conserve water, however, excrete uric acid or urea and are therefore called as **uricotelic or ureotelic** organisms respectively, depending upon the nature of excretory product. Uric acid requires very little water during excretion while urea requires moderate amount. Thus, fishes are **ammonotelic** whereas reptiles (snakes and lizards) and birds are **uricotelic** and mammals including man are **ureotelic** in nature.

Excretory Structures in different animals

1. Diffusion through cell membrane, *Amoeba,* sponge, etc.
2. Nephridia—earthworm
3. Flame cells—Flat worms
4. Malpighian tubules—Insects
5. Kidneys—Man

In the animal world, there are many different types of organs of excretion viz. flame cells, or malpighian tubules in lower animals and kidneys in human beings. The nitrogenous wastes are removed from the body in man, in the form of **urine**, effected by **kidneys**.

Structure

There are a pair of **bean-shaped** kidneys in human beings and each kidney in turn is made up of about one million tiny, highly coiled similar units, known as **nephrons**. Each nephron is made up of two basic components: (1) **The blood vascular component** and (2) **The tubular component**

(1) The blood vascular component includes (i) a highly coiled tuft of capillaries—the **glomerulus** and (ii) a branching capillary network surrounding the uriniferous tubules — the **pericapillary tubular network.**

(2) The tubular component, on the other hand, comprises of (i) a blind, double-walled cup—the **Bowman's capsule** and (ii) coiled tubes—the **proximal and distal convoluted tubules** and **a collecting duct**.
(Please refer to the Fig. B.6.5(a))

The collecting ducts from various nephrons (one million) join together and open into the **pelvis**, which in turn drains urine into **urinary bladder**, through a pair of **ureters**.

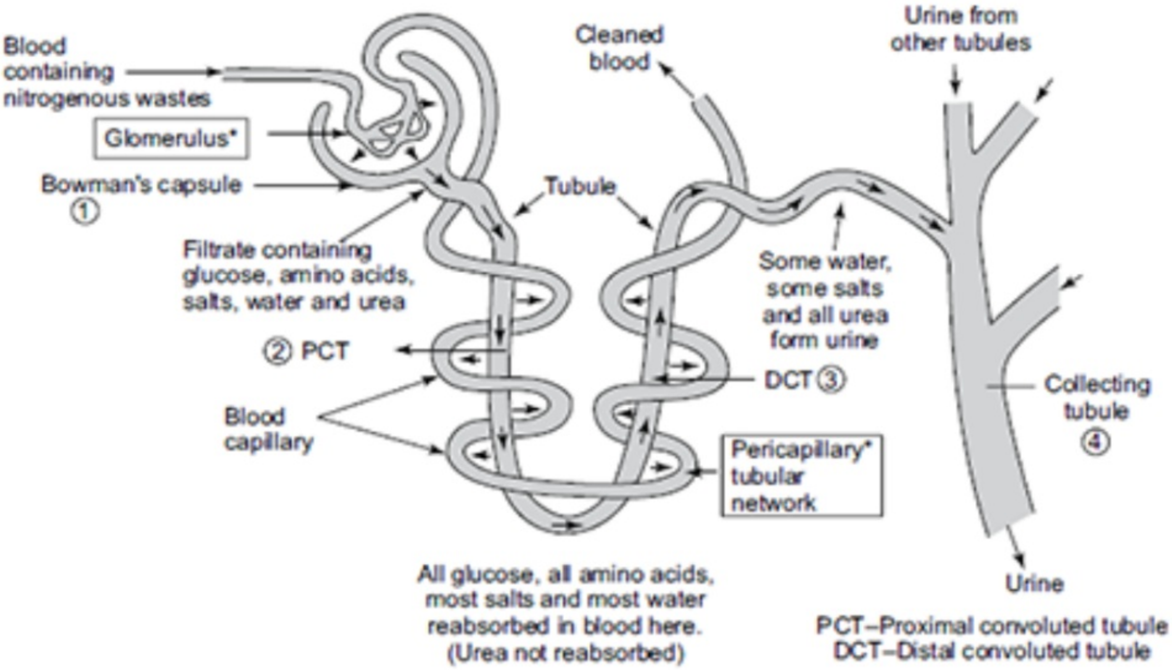

Blood containing nitrogenous wastes
Glomerulus*
Bowman's capsule ①
Filtrate containing glucose, amino acids, salts, water and urea
② PCT
Blood capillary
Tubule
Cleaned blood
Urine from other tubules
Some water, some salts and all urea form urine
DCT ③
Pericapillary* tubular network
Collecting tubule ④
All glucose, all amino acids, most salts and most water reabsorbed in blood here. (Urea not reabsorbed)
Urine
PCT–Proximal convoluted tubule
DCT–Distal convoluted tubule

Figure B.6.5(a)

Working of Human Excretory System

Mechanism: Urine Formation

The kidneys form urine, and while carrying out this process, perform its main functions, namely:

(i) The excretion of nitrogenous waste products and

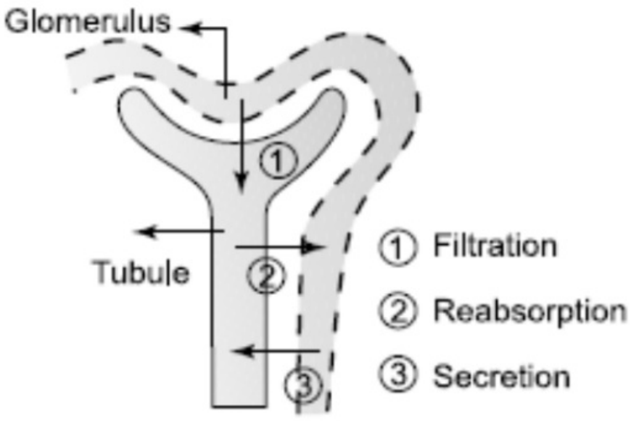
(ii) **"Homeostasis"** or maintaining stable, constant conditions of internal environment. Some of the homeostatic functions of the kidney are:

* Maintenance of pH (**or acid-base balance**). It is brought about mainly by phosphate buffers (you must have learnt about buffers in your chemistry section)

** Maintenance of ion concentration (Na^+, K^+, H^+, Cl^-, HPO_4^{2-}, etc.), and

*** Maintenance of Osmotic pressure.

The figure shows a diagrammatic representation of the relationship between the vascular and tubular component of a nephron. [Fig. B.6.5(b)]. If the direction of the movement of fluid and dissolved solutes is from the tubule to blood stream (capillary network), it is called as **tubular reabsorption** and if it occurs in the opposite direction, i.e., from the *blood stream to tubular lumen*, then it is known as **tubular secretion.** These two processes help in urine formation.



(b)

Figure B.6.5(b)

The process of **urine formation** by the kidneys essentially involves three basic processes:

(i) **Glomerular Filtration**—This refers to the movement of fluid and dissolved solutes by **force or pressure** (blood pressure) from the glomerulus to Bowman's capsule, through small pores or openings called as "**filtration slits**".

The process is somewhat similar to "*straining of tea*" through "tea strainer". Here, tea is equivalent to "blood";

pores in the strainer = filtration slits.

strainer = Bowman's capsule.

& tea leaves are = proteins & blood cells which are not allowed to pass.

Only small molecules of substances present in the blood viz. glucose, amino acids, urea, water, salts, etc. can pass through the openings of the glomerulus and collect as filtrate in the Bowman's capsule. The fluid finally present in the capsule after filtration is known as **ultra-filtrate** and the process is known as **Glomerular Filtration**. The glomerular filtration rate (**GFR**) in adult man is **120 ml/mt or 180 litres/day**.

(ii) **Tubular reabsorption**: The glomerular filtration rate of human kidney is 180 litres/day, whereas if the rate of urine formation is measured, it is found to be only 1–2 litres/day!! This indicates that **more than 99% of water that is filtered through glomerulus re-enters the blood stream (i.e., reabsorbed),** as it passes through the various tubules. Not only this, if we compare the **volume and composition of final urine** that is formed with that of the glomerular filtrate, it shows that many of the components that were originally present in the filtrate, are either **missing or present in much lower concentrations** in the urine. This indicates that water and these components are subjected to a process known as **tubular reabsorption**. Some solutes like glucose, amino acids, vitamins, Na^+, HCO_3^-, etc. are reabsorbed by **active reabsorption** involving *utilisation of energy* whereas chloride ions, urea, etc. are reabsorbed by **passive reabsorption,** i.e., without the use of energy.

Reabsorption of water is known as **obligatory** or compulsory when it's linked to the movement of sodium/chloride ions. Whereas, it is called **facultative** or optional, when it's influenced by the presence or absence of **Anti Diuretic Hormone** (ADH). The name is derived from two words—"anti" meaning opposing and "diuresis" meaning urine formation. Thus, this **hormone opposes urine formation**, when present. It is released by the posterior pituitary gland. In fact, this hormone helps kidneys to **excrete a concentrated urine** and hence conserve water in the conditions of scarcity, such as, when a person is present in a desert! Formation of concentrated urine is further brought about by a unique process, called as **countercurrent mechanism**, carried out by the human kidneys.

(iii) **Tubular Secretion**: Some substances are not useful for the body and therefore have to be removed by the kidneys. This is done by **tubular secretion,** e.g., potassium ions (K^+), hydrogen ions (H^+), creatinine, etc. These substances are present in greater concentration in urine than in the filtrate, because of tubular secretion.

Dialysis

If a person's kidneys are diseased or injured they're unable to function normally, and therefore the blood of the patient needs to be **cleansed artificially by dialysis**. Dialysis separates large solutes from smaller ones by using a selectively permeable membrane.

Clinical disorders of Excretory System

Renal calculi or kidney stones

The crystals of salts present in urine occasionally precipitate and solidify into insoluble stones of calcium oxalate, uric acid or calcium phosphate, blocking a narrow passage viz. ureters causing intense pain.

B.6.6 HORMONES AND ENDOCRINE SYSTEM

The human body, which works like a very efficient, coordinate and tireless machine, carries out many different complex functions at a time. There is rarely a conflict or malfunction between its varied activities (It occurs only in case of diseases). This miracle is achieved by the body's "**homeostatic**"[1] mechanisms. Homeostasis is maintained mainly by the nervous system and the **endocrine system** as well as partly by the kidneys. This word is derived from "endo" meaning internal and "crine" meaning secretion. Thus, it's a system of glands which produces "secretions" which are released in the "interior" of the body, i.e., in the **blood stream** directly. There are several **endocrine glands (the, ductless glands)** present in the body, which pour their **secretion** directly into the **blood stream which in turn carries it to the target organ**.

This secretion is known as **hormone**[2]. The hormone exhibits its specific effect on the target gland, which is located far away from the site of secretion.

Table B.6.4 summarises the list of chief endocrine glands, their location and type of **hormones** and diseases associated with each gland.

Table B.6.4

Principal Endocrine Glands, Their Location, Secretions and General Effect Upon the Body

Gland	Location	Hormone/s	Effect	Diseases associated with the gland
(1) Hypothalamus	Below thalamus and connected to pituitary by hypophyseal stalk at the base of brain	**Releasing hormone** (RH) for each anterior pituitary hormone: (& **Inhibiting hormone** for some) GH--RH, TSH--RH, ACTH--RH, FSH--RH, LH--RH and LTH—RH	Production of all the anterior pituitary hormones is controlled by messages (**Releasing hormones**) from the hypothalamus. Releasing hormones pass from hypothalamus to the anterior pituitary via **hypothalamo-hypophyseal portal vessels**.	
(2) Pituitary or Hypophysis	*present* below hypothalamus in sphenoid bone			
Anterior lobe		(a) **Growth hormone (GH),** also called Somatotrophic hormone (STH)	Stimulates all tissues viz. liver, muscle, etc. and influences the **growth of long bones**, promotes protein synthesis, tissue repair	(a) Insufficient secretion of GH during growing years slows down bone growth, resulting in **pituitary dwarfism**. **Excessive** secretion, **during childhood** causes **gigantism** whereas during **adulthood** results in **acromegaly.**
		(b) **Thyroid stimulating hormone** (TSH)	Stimulates the synthesis and secretary activity of the thyroid gland	
		(c) **Adrenocorticotrophic hormone** (ACTH)	Stimulates the production of corticosteroids by **adrenal cortex only**—the hormones involved in defending the body **against**	

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[1] ["Constant internal environment", means stable or constant conditions in the extracellular fluid or blood w.r.t. water concentration, ion-concentration (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2}, etc.) pH, glucose concentration, body temperature, arterial pressure, basal metabolic rate, etc.]

[2] A hormone is a **chemical messenger** (like an enzyme) which is secreted by endocrine (ductless glands) and hence released directly into blood stream. Its chemical nature can be a protein, steroid, biogenic amine, etc.

			physiological stress	
		(d) **Follicle-stimulating hormone** (FSH)	Promotes the growth and maturation of follicles in the ovary, production of female sex hormone, estrogen, and maturation of spermatozoa in the male.	
		(e) **Luteinizing hormone (LH**)	Stimulates interstitial (**Leydig**) cells in the testis to produce male sex hormone, testosterone; causes ovulation, release of estrogen and formation of corpus luteum in female.	
		(f**) Luteotrophic hormone (LTH) or prolactin**	Helps to maintain pregnancy, secretion of progesterone, to stimulate mammary glands to secrete milk, together with other hormones	
	Middle lobe (not well developed in human beings)	**Melanophore stimulating hormone (MSH)**	Associated with growth and development of **melanocytes** that give skin its colour (not important in human beings but important in lower animals viz. fishes, frogs, etc.)	
	Posterior lobe (Neurosecretory cells of hypothalamus **secrete** the hormone & posterior pituitary **only stores & releases** it, when needed)	(a) **Antidiuretic hormone ADH), also called Vasopressin**	Controls *water* **reabsorption** in the kidney tubule, thus regulating water and salt balance of body fluids, raises blood pressure by causing constriction of blood vessels	Inability to secrete ADH causes **diabetes insipidus** (excretion of large volumes of urine, dehydration & thirst)
		(b) **Oxytocin**	Causes **uterine contractions** during child-birth and causes milk ejection during and after birth.	
(3) Thyroid	Base of neck at lower extremity of	(a) **Thyroxine**	Increases **basal metabolic rate** (BMR), i.e., regulates basal metabolism,	Low secretion of thyroid hormones *during* childhood causes **cretinism** (severe

	larynx		influences heat production, stimulates synthesis of proteins, essential for mental and physical development.	mental retardation) and during *adult years* produces **myxedema** (no mental retardation but a patient shows slow heart rate, low body temperature, face swells, dry hair and skin etc.) *High* secretion of TSH causes **Grave's disease** (protruding eyes) **Goiter**- enlarged thyroid gland.
		(b) **Calcitonin**	Reduces blood calcium level	
(4) Parathyroids	Four in number, embedded within the substance of thyroid gland	**Parathyroid-hormone (PTH)**	Raises blood calcium level	Too little PTH leads to deficiency of Ca^{2+}, resulting in **tetany** (sustained contraction of muscles)
(5) Adrenals	Located at the top of each kidney			
	(a) **Adrenal cortex**	(a) **Glucocorticoids (viz cortisol)**	Regulate metabolism of **carbohydrates**, proteins and fats, help to fight the **stress** (associated with surgical shock, pain, extreme emotional distress and severe cold by elevating blood glucose due to conversion of protein in to glucose)	**Under secretion** of glucocorticoids and aldosterone causes **Addison's disease** (low blood pressure, decreased heart rate, dehydration & even cardiac arrest) Hypersecretion of cortisol produces **Cushing's syndrome**, characterised by redistribution of fat, resulting in spindly arms and legs, accompained by a rounded "moon face," "buffalo hump" and pendulous abdomen.
		(b) **Mineralocorticoids (viz aldosterone)**	Act at kidney tubule to prevent Na^+ and water to pass in the urine and to increase K^+ secretion	
		(c) **Gonadocorticoids** (viz androgens)	Androgens are "male" sex hormones, but they are also present in very minute amounts in females, because of secretion by adrenal cortex	
	(b) **Adrenal medulla**	**Epinephrine and Norepinephrine**	Help the body in handling **emergency situations** of	

		(E&NE) (Also known as “Fight-or-Flight” hormone)	extreme danger or fright by increasing the heart rate, by raising blood pressure and by elevating blood glucose level.	
(6) Pancreas (Islets of Langerhans)	Islets lie scattered between the pancreatic acini	(a) **Insulin** (b-cells)	(a) **Lowers the blood glucose level (hypoglycemic)**	Inability to produce or use insulin causes **diabetes mellitus** (blood glucose level high therefore it’s higher in urine also)
		(b) **Glucagon** (a-cells)	(b) **Elevates the blood glucose level (hyperglycemic)**. The interactions of these two hormones help **maintain blood glucose level at** a steady 100mg/100ml.	
		(c) **Somatostatin** (d-cells)	(c) Acts opposite to Growth Hormone	
(7) Ovaries	Theca interna in Graaflan follicle	(a) **Estrogen**	(a) Controls the **development of secondary sexual characteristics of the** female, viz. breasts, pubic hair, deposition of fat on thighs, enlargement of uterus, vagina, menstruation and development of sexual heat.	
		(b) **Relaxin**	(b) Relaxes public symphysis during pregnancy and helps in delivery of the baby.	
		(c) **Inhibin**	(c) Inhibits FSH	
	Corpus luteum	(d) **Progesterone**	Prepares the inner lining of uterus (endometrium) for **implantation of young embryo**, and also maintains it during pregnancy, prepares mammary glands for milk production.	
(8) Testes	**Interstitial or Leydig** cells located in narrow, angular spaces between seminiferous tubules	(a) **Testosterone**	(a) Controls the development of **secondary sexual characteristics of the male**, viz. enlargement of penis and scrotum, pubic hair, deepening of the voice and development of sexual desire (libido).	
		(b) **Inhibin**	(b) Inhibits FSH	

(9) Pineal	Roof of the brain	**Melatonin**	Sets "biological clock" of the body, regulates "sleep & awake" cycle.

Summary of Hormones Produced by Non-endocrine Glands

Stomach G-cells	**Gastrin**	**Promotes secretion of HCl by parietal cells**
Small Intestine	(a) Secretin	(a) Stimulates secretion of pancreatic juice & bile
	(b) Cholecystokinin (CCK)	(b) Regulates the release of bile by contraction of the gall bladder.
Kidneys	(a) Erythropoietin	(a) Increases rate of **red blood cell** formation
	(b) Calcitriol* (active form of vitamin D)	(b) Helps in absorption of calcium.
Heart	Atrial natriuretic peptide (ANP)	Decreases blood pressure
Placenta	(a) Human Chorionic Gonadotropin (hCG)	(a) Stimulates production of estrogens & progesterone to maintain pregnancy
	(b) Human Chorionic Somatomammotropin (hCS)	(b) Stimulates mammary glands for milk secretion
Adipose tissue	(a) Leptin	Suppresses appetite, reduces weight

Pheromones

Hormones, are chemical messengers secreted by the **endocrine glands.** They carry messages, **inside the body**, through blood stream from one part of the body to the target organ. At the same time, there are also certain chemicals that **carry information outside** the body to other members of the same species. These are known as **pheromones or ecto-hormones**. These are chemical substances released by an animal into its surroundings which influences the behavior or development of the individuals of the same species, e.g., in insects, females release **sex attractants, queen bee substance** in honey bees, **alarm pheromones** in termites and bees, and **trail pheromones** in ants, etc.

B.6.7 THE SKELETAL SYSTEM

The complete framework of bones and cartilage together forms the **skeletal system**. **The adult human keleton consists of 206 bones** and is divided into two main divisions: **(i) Axial skeleton and (ii) Appendicular skeleton**

(i) Axial skeleton consists of bones that lie along the **main axis of the body,** e.g., ribs, vertebral column and skull and comprises of **80 bones.**

(ii) Appendicular skeleton consists of bones which lie **around or on** sides of the main axis of the body, e.g., upper and lower limbs and girdles—shoulder & hip girdle and comprises of **126 bones.**

Types of Bones

Bones can be classified on various bases. There are five main types of bones, based on **shape—** (1) **Long bones**—They have greater length than width, e.g., bones of thigh, leg, arm, forearm, etc. (2) **short bones**—These are cube shaped, e.g., wrist and ankle bones (3) **Flat bones**—They are thin, plate-like, e.g., bones of the skull, breast bone, etc. (4) **Irregular bones** – They have complex shapes, e.g., vertebrae of the backbone. (5) **Sesamoid bones** – These are shaped like a "seasame" seed, e.g., knee cap, palm and sole. They develop in certain tendons where there is considerable friction, tension and physical stress.

An additional type of bone, which is classified by **location**, instead of shape is **sutural bone**. These are small bones located within joints, between cranial bones.

Further, there are two types of bones, on the basis of **development** (1) **Membranous bones** or dermal bones, which are formed by intra-membranous ossification, and (2) **Cartilagenous bones**, which ossify from cartilage model.

On the basis of **region**, there are four more types of bones: (1) **Compact bone**—They have more bone tissue than space (2) **Spongy bone**—They have more empty space than bone tissue (3) **Lamellar bone**—These are made of thin plates or lamellae and (4) **Fibrous bones**—They are made of more fibres. In humans, these are found only in the foetus.

Joints

The skeletal system is made up of many bones, which are joined at certain points, known as joints. These joints act as "hinge" and are responsible for changing positions of the bones or bringing about movements of the bones. A joint is a point of contact between two bones, between cartilage and bones, or between teeth and bones.

There are various types of joints viz. (1) **Fibrous joints**: The bones are held together by fibrous connective tissue without synovial cavity. Therefore, it permits **no movement**, e.g., sutures in skull, (2) **cartilaginous joints**: The bones are held together by cartilage, without synovial cavity. These are **partially movable,** e.g., public symphysis (3) **Synovial joints**: The bones forming this joint have a **synovial cavity**, united by dense irregular connective tissue, articular cartilage or by ligaments. These are **freely movable,** e.g., elbow and ankle joint, radius and ulna, etc.

Functions

(a) It provides support to the body. (b) It protects the internal organs. (c) It helps in movement. (d) It maintains mineral balance particularly of calcium and phosphorus. (e) It forms blood cells in **red bone marrow.** Red bone marrow is a connective tissue within certain bones viz. pelvis, ribs, backbone and ends of arm and thigh bones, which produces RBCs. (f) It stores triglycerides. Adipose cells of **yellow bone marrow** store triglycerides. These are an important **chemical energy reserve**. **(In a newborn, all bone marrow is red and is involved in RBC production but with increasing age much of it changes from red to yellow).**

Largest bone in the human body – femur
Smallest bone in the human body–stapes

Clinical disorders of the Skeletal System

(1) *Rheumatism* is a painful disorder of the supporting structures of the body viz. bones, muscles, ligaments and tendons.
(2) *Arthritis* is a form of rheumatism, in which joints are swollen, stiff and painful.
(3) *Rheumatoid arthritis* is an autoimmune disease in which the immune system attacks its own cartilage and joint linings, causing inflammation of joints, swelling, pain and loss of function.
(4) *Gout* is a metabolic disorder in which high levels of uric acid are present in the blood. Crystals of its salt (sodium urate) accumulate in soft tissues viz. kidneys and cartilage of ears and joints, causing inflammation, swelling, acute pain and finally immovable joints.
(5) *Osteoporosis* ("Osteo" = bone; "Por" = passage way; "Osis"= condition). It is literally a condition of **porous bones** due to depletion of calcium from the body. It makes bones so weak and depleted that they fracture spontaneously or with very little stress, e.g., by simply sitting down too quickly.
This disorder primarily affects middle aged and elderly women at menopause because of decline of estrogens.
(6) *Tennis elbow* commonly refers to pain at or near the epicondyle of the humerus, usually caused by an improperly executed backhand. The extensor muscles strain or sprain, resulting in pain. This disease has become a "national" concern, because "The God of Cricket", Sachin Tendulkar is afflicted with this problem.

B.6.8 REPRODUCTION

The single, most dominant feature which distinguishes a living organism from a non-living material, is that the living organisms **can produce their own kinds** whereas a non-living material cannot!! Thus, the biggest strength of a living organism is its inherent ability or desire to perpetuate, i.e., **reproduction**. It is also essential for the **survival of the species** on this earth.

There are basically two ways by which animals can reproduce: (i) **asexual reproduction**

(‘A’ absence, i.e., absence of sexual method): It is a type of reproduction in which new individuals are produced by non-sexual or vegetative methods, without involving the two sexes and (ii) **sexual reproduction:** This is another type of reproductive method in which male and female sex cells (**gametes**) fuse to form a new individual (***zygote***). It is seen in higher animals like horse, dog, man, cat, etc.

Asexual Reproduction

Asexual reproduction can occur by following mechanisms:

(i) **Fission**: Many simple organisms like protozoa and bacteria just divide or split into identical halves, forming new organisms. It can be **binary fission,** i.e., division of original or parental cell into **two** daughter cells or **multiple fission**, into **many** daughter cells, e.g., *Amoeba,* malarial parasite, etc.

(ii) **Fragmentation**: This involves breaking off of parts or fragments of the parental organism. Each part subsequently grows to form a complete new organism, e.g., flatworm.

(iii) **Budding**: In this type of reproduction, a small outgrowth or “bud” sprouts from the parent organism, which later grows into a complete individual, e.g., sponges, *Hydra*, etc.

Sexual Reproduction

The basic precondition for this type of reproduction is fusion of male gametes known as “**sperms**” and female gametes—the “**ova**” or eggs, to form the **zygote** or embryo. In simple terms, zygote is a “fertilised ovum” or fertilised egg. The **union or fusion** of male and female gametes to form a zygote, during sexual reproduction, is called **fertilisation**.

Sexual Reproduction leads to increased genetic variation in population because offsprings receive genes from both the parents, which get mixed during fertilisation (**meiosis**). Further by providing genetic variation, sexual reproduction leads to **origin of new species, i.e., evolution.**

Fertilisation

The **fertilisation** is of two types: (i) **Internal Fertilisation—**In this type of fertilisation, union of male and female gametes occurs inside the female body, e.g., birds, reptiles, and mammals (including human). But, note that the birds and reptiles “**lay eggs**” or are **oviparous** whereas mammals “**produce offsprings**” and hence are **viviparous**”. **In man, fertilisation occurs in the oviduct.** (ii) **External Fertilisation**—In this type of fertilisation, male and female animals release their sperms and eggs in the surrounding medium, where fertilisation takes place, e.g., frogs, toads, fishes, etc.

Male Reproduction System

The gametes are produced by male and female reproductive structures, known as **gonads**. The male gonads in human beings are a pair of **testes** which are located in the **scrotal sacs**. The testes descend in foetal life in these sacs which are located outside the main body cavity. This is a physiological adaptation to ensure survival of the sperms at relatively low temperature. Besides testes, which are the main reproductive organs, there are some **accessory structures**, too, like a pair of vasa deferentia, seminal vesicles, ejaculatory ducts, a prostate gland and penis, etc.

Spermatogenesis

(Sperm"; "genesis" = Formation): The process of formation of sperms from the primordial mother cells is known as spermatogenesis. It involves a sequence of events underlined below:

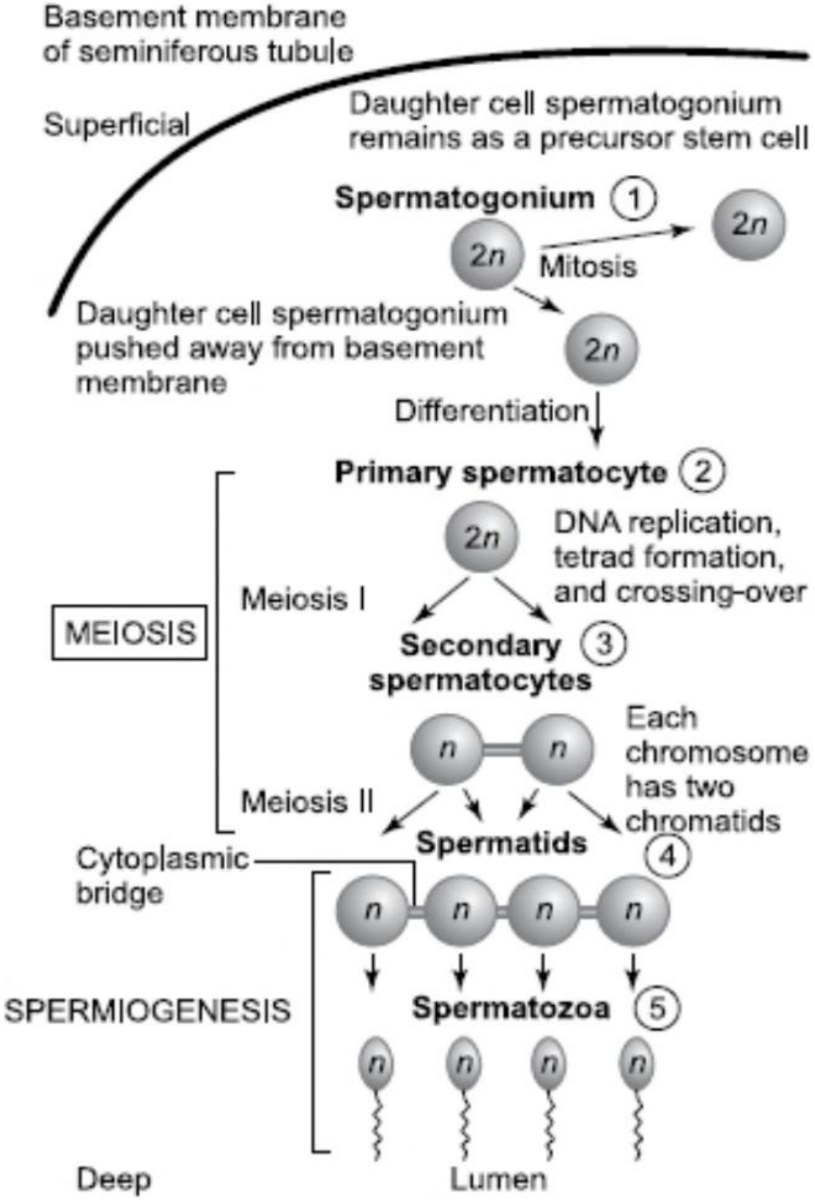

Basement membrane of seminiferous tubule
Superficial
Daughter cell spermatogonium remains as a precursor stem cell
Spermatogonium ①
2n
Mitosis
2n
Daughter cell spermatogonium pushed away from basement membrane
2n
Differentiation
Primary spermatocyte ②
2n
DNA replication, tetrad formation, and crossing-over
MEIOSIS
Meiosis I
Secondary spermatocytes ③
n
n
Each chromosome has two chromatids
Meiosis II
Spermatids ④
Cytoplasmic bridge
n
n
n
n
SPERMIOGENESIS
Spermatozoa ⑤
n
n
n
n
Deep
Lumen

Figure B.6.6

Female Reproductive System

This comprises of female gonads, i.e., a **pair of ovaries** with associated structures viz. a pair of oviducts (fallopian tubes), vagina ("birth canal") and **uterus,** etc. Uterus is meant for the anchorage of the **fertilised ovum** (i.e., zygote) or **blastocyst** to its wall, called as **implantation** and therefore commonly known as "**womb**".

Note: Opening for passage of urine (*urethra*) and *vagina are separate in females* as opposed to males.

Oogenesis

Both the gonads play a dual role: (i) **cytogenic,** i.e., formation of gametes and (ii) **endocrine,** i.e., secretion of male and female sex hormones such as Testosterone in male and Oestrogen and Progesterone in females.

The process of formation of mature egg or ovum from primordial mother cells is known as oogenesis. The sequence of events in oogenesis is outlined below in Fig. B.6.7:

Puberty

The age of puberty for girls is 10–12 years and for boys 13–14 years. The age at which male and females are "**sexually mature**" is known as **puberty**. At puberty the reproductive organs attain maturity and therefore produce gametes, as well as hormones.

Menstrual Cycle

It is the cyclic activity manifested by the uterine wall of **primates only,** resulting in bleeding or **menstruation**. Bleeding is caused due to the breakdown of the innermost wall of uterus (*endometrium*), causing the underlying blood vessels to rupture. It lasts for 28 days. The breakdown or removal of inner, thick and soft lining of the uterus along with the blood and mucus, in the form of vaginal bleeding is called menstruation.

Sub-primates also show cyclic activity in females. It is known as **estrous cycle**.

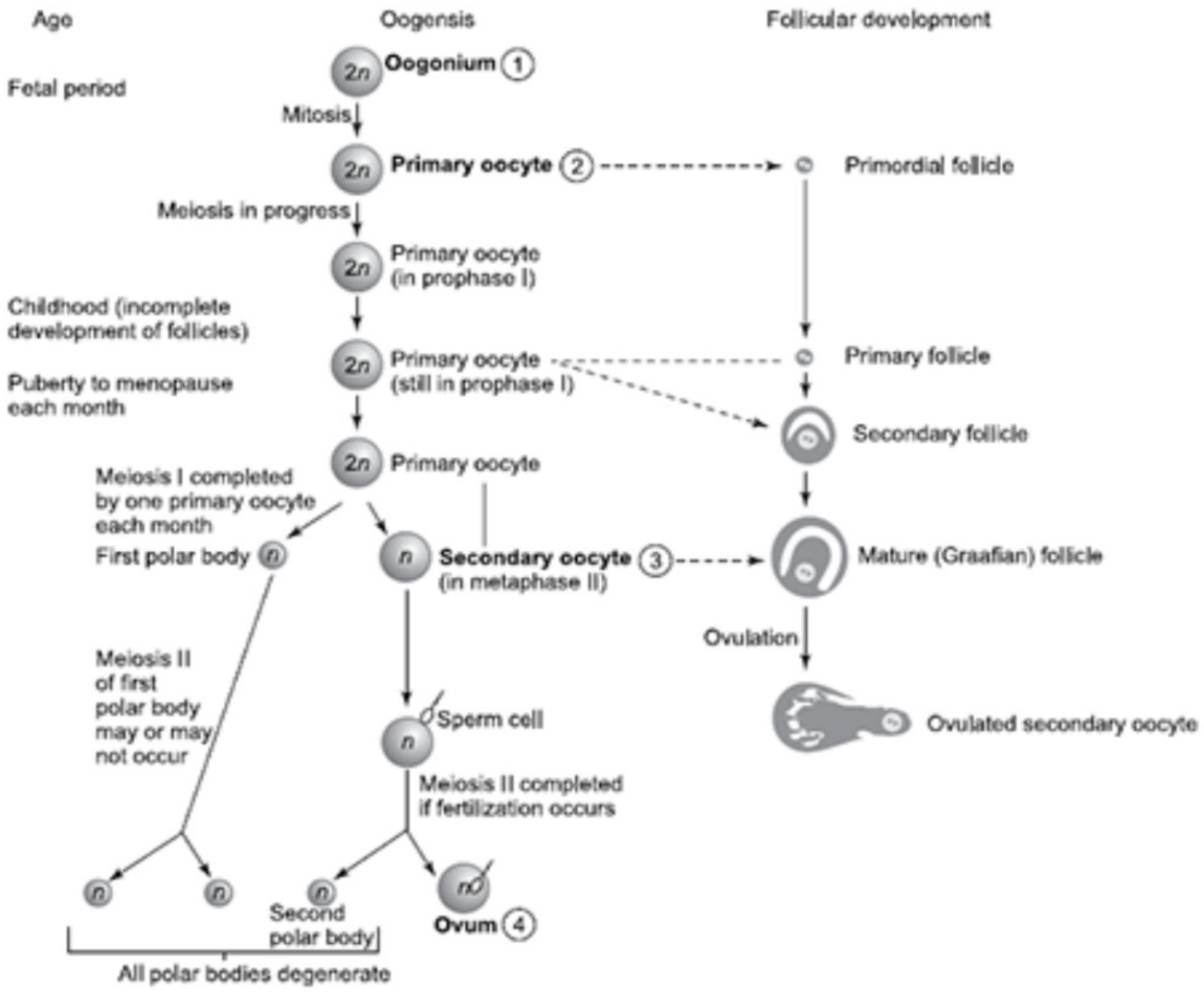

Age
Oogensis
Follicular development
Fetal period
2n
Oogonium ①
Mitosis
2n
Primary oocyte ②
Primordial follicle
Meiosis in progress
2n
Primary oocyte (in prophase I)
Childhood (incomplete development of follicles)
2n
Primary oocyte (still in prophase I)
Primary follicle
Puberty to menopause each month
Secondary follicle
2n
Primary oocyte
Meiosis I completed by one primary oocyte each month
First polar body
n
n
Secondary oocyte ③ (in metaphase II)
Mature (Graafian) follicle
Ovulation
Ovulated secondary oocyte
Meiosis II of first polar body may or may not occur
Sperm cell
n
Meiosis II completed if fertilization occurs
n
n
n
Second polar body
n
Ovum ④
All polar bodies degenerate

Figure B.6.7

Summary of Oogenesis and Follicular Development

Menopause or Female Climacteric

(“Pause” means stoppage and “meno” stands for menstrual cycle). Thus, it refers to **physiological stoppage of menstrual flow**. It occurs between the age of 45–50 years, due to decrease in female sex hormone production (viz. estrogen). It also marks the termination of follicle development in the ovaries and the end of child bearing period.

Some terms associated with reproductive system:

Placenta: The special connection through which the exchange of materials (viz. oxygen, CO_2, waste materials, food, etc.) between fetal and maternal circulations occurs. It's also known as **after-birth**.

Parturition: (“part” = separate or move away) Separation of foetus from the uterine wall of the mother, i.e., *act of giving birth to young foetus*.

Gestation: The period of development from fertilisation to birth is known as gestation.

Parthenogenesis ("virgin birth"): It is the development of an organism without fertilisation. In some species, eggs can develop on their own, when stimulated without fusion with the sperm.

This **development** of an **unfertilised egg** into an adult is known as **parthenogenesis,** e.g., plant lice, thrips, ants, bees, wasps, etc.

Jacques Loeb demonstrated that some animals viz. sea urchins, frogs and salamanders can be stimulated to develop by applying **external stimuli**, which includes pricking, shaking, heating, subjecting to dilute organic acids or high salt solution. This is known as **artificial parthenogenesis** and many of these animals have been produced by this method, including a rabbit.

Paedogenesis: It is an act of producing young while in immature or larval state, e.g., certain insects, amphibians, etc. In other words, it is a reproduction by sexually mature young or larval animals, usually without fertilisation. This is also known as **Neoteny**.

Birth Control Methods

(i) Complete abstinence (avoidance of sexual intercourse)

(ii) Surgical sterilisation

- Vasectomy (a portion of ductus deferens is cut or removed).
- Tubal ligation (both uterine tubes tied and then cut).

(iii) Hormonal methods

- Oral contraceptives (Estrogens and Progestin)
- Norplant (Progestin)
- Depo-provera (hormone-progestin)

(iv) Intra-uterine device

- Copper T

(v) Spermicides viz. foams, creams, jellies, douches, etc.

(vi) Barrier methods

- Male condom
- Vaginal pouch
- Diaphragm

Sexually Transmitted Diseases

1. **Gonorrhea** caused by bacterium *Neisseria gonorrhoeae*
2. **Syphilis** caused by bacterium *Treponema pallidum*
3. **Genital Herpes** caused by Type II herpes simplex virus (HSV-2)
4. **Genital Warts** caused by virus *Human papilloma virus* (HPV)

Clinical disorders of Reproductive System

(1) *Cryptorchidism* (“crypt” = hidden; “orchid” = testis): The condition in with testes do not descend into the scrotum.

(2) *Inguinal hernias*: Inguinal region is a weak area in the abdominal wall. Rupture or separation of a portion of the inguinal area of the abdominal wall results in the protrusion of a part of the small intestine into scrotum. This is known as *inguinal hernia*.

(3) *Circumcision* (to cut around): It is a surgical procedure in which part or the entire prepuce (*foreskin covering the penis*) is removed. It is usually performed just after delivery, 3–4 days after birth, or on 8th day as part of a *Jewish religious rite.*

(4) *Hysterectomy* (“hyster” = uterus): It is the surgical removal of the uterus. It may be indicated in conditions viz. endometriosis, pelvic inflammatory disease, ovarian cyst, excessive uterine bleeding and cancer of the cervix, uterus or ovaries.

(5) *Amenorrhea* (‘a’ = absence; “men” = month; “rrhea” = a flow): It refers to absence of menstruation.

(6) *Dysmenorrhea* (“dys” = difficulty or painful) is painful menstruation.

(7) *Premenstrual Syndrome* (PMS) is a cyclical disorder of severe physiological and emotional stress before menstruation.

B.6.9 THE NERVOUS SYSTEM

Nervous system is one of the smallest and yet most complex and important system in linking and integrating every cell or tissue with each other. It is the **major “homeostatic”** mechanism along with endocrine system. The nervous system serves as a “master” which controls and coordinates all parts of our body viz. reading, writing, walking, talking, dancing, etc., which require “thinking” as well as actions like breathing and heart beat, which occur without thinking!! Further, because of its property of carrying information from one part of the body to the other, it also serves as a means of **biocommunication**. One of the basic features of a living organism is **response to the environment** or reaction to stimuli—both external as well as internal. This function is also brought about by nervous system, e.g., plants bend towards light, we pull our hands away from the hot object and A*moeba* moves towards food, etc. This system is responsible for perceptions, behaviour, and memory in human beings too, which made him reach to the pinnacle of the evolutionary tree!!

The nervous system is made up of millions of units called as **neurons** (about 100 billion in brain alone!!) as well as some supporting cells—**the neuroglial cells** in humans.

Organisation of the Nervous System

The nervous system is organised into two main divisions:

(a) The central nervous system (CNS) and (b) the peripheral nervous system (PNS)

(a) **The Central Nervous System**

The central nervous system comprises of the brain and the spinal cord

(b) **The Peripheral Nervous System**

The peripheral nervous system consists of nerve cells lying outside the CNS. It is further sub-divided into: (i) Autonomic nervous system, (ii) Somatic nervous system, and (iii) Enteric nervous system.

(i) **Autonomic Nervous System (ANS)** (“auto” = self; “nomos” = governing) In ANS the receptors are located in **internal** organs and hence it is **involuntary** in nature. Further, it comprises of two sub-divisions:

- Sympathetic nervous system and
- Parasympathetic nervous system. Nerve fibre endings of sympathetic nervous system release Epinephrine/Nor-epinephrine as a neurotransmitter and that of parasympathetic nervous system release Acetylcholine. The two systems act opposite to each other, e.g., sympathetic nerve fibres increase the heart rate whereas parasympathetic system decreases it

(ii) **Somatic Nervous System (SNS)**

In the SNS, receptors are found in skin, limbs and upper part of the body. It also includes special **sense organs** viz. eye, ear, nose, etc.

(iii) **Enteric Nervous System (ENS)**

Once considered part of the ANS, it is also known as the “brain of the gut”. It consists of approximately 100 million neurons and its operation is involuntary.

Structure of Brain, Spinal Cord and Their Functions

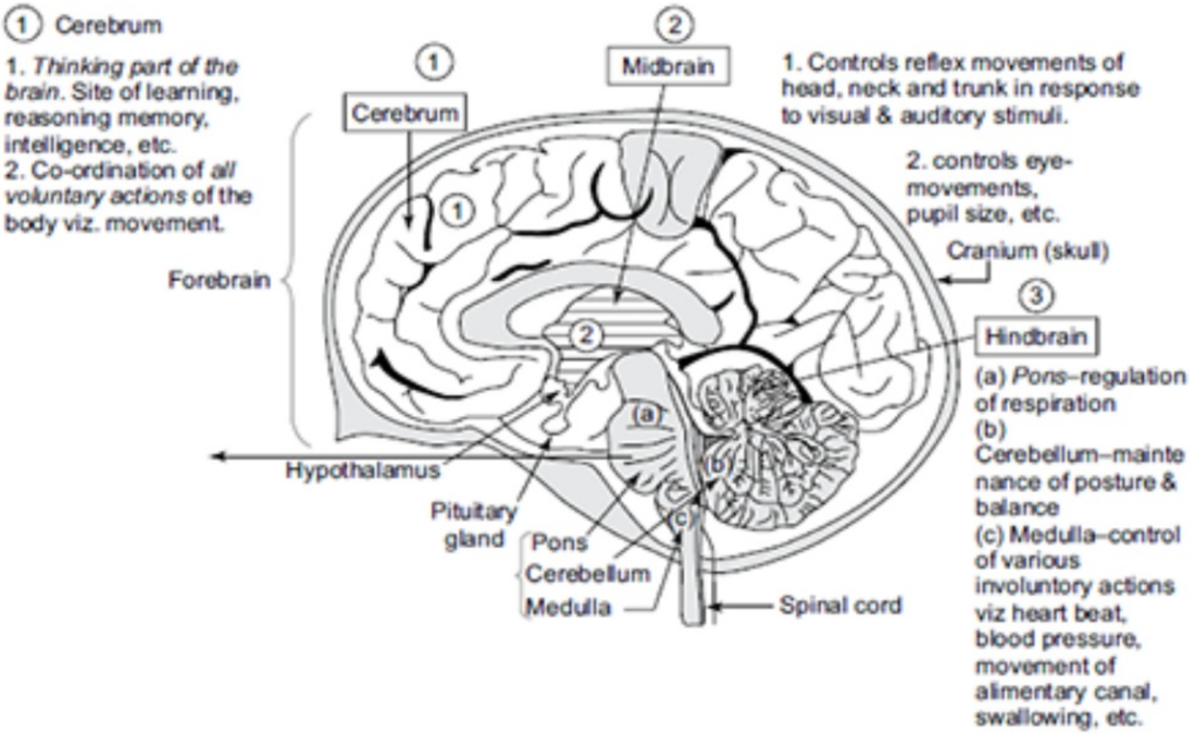

① Cerebrum
1. Thinking part of the brain. Site of learning, reasoning memory, intelligence, etc.
2. Co-ordination of all voluntary actions of the body viz. movement.
Forebrain
①
Cerebrum
①
②
Midbrain
1. Controls reflex movements of head, neck and trunk in response to visual & auditory stimuli.
2. controls eye-movements, pupil size, etc.
Cranium (skull)
②
③
Hindbrain
(a) Pons–regulation of respiration
(b) Cerebellum–maintenance of posture & balance
(c) Medulla–control of various involuntory actions viz heart beat, blood pressure, movement of alimentary canal, swallowing, etc.
(a)
(b)
(c)
Hypothalamus
Pituitary gland
Pons
Cerebellum
Medulla
Spinal cord

Figure B.6.8

The human brain with its functions

Structure of Neuron

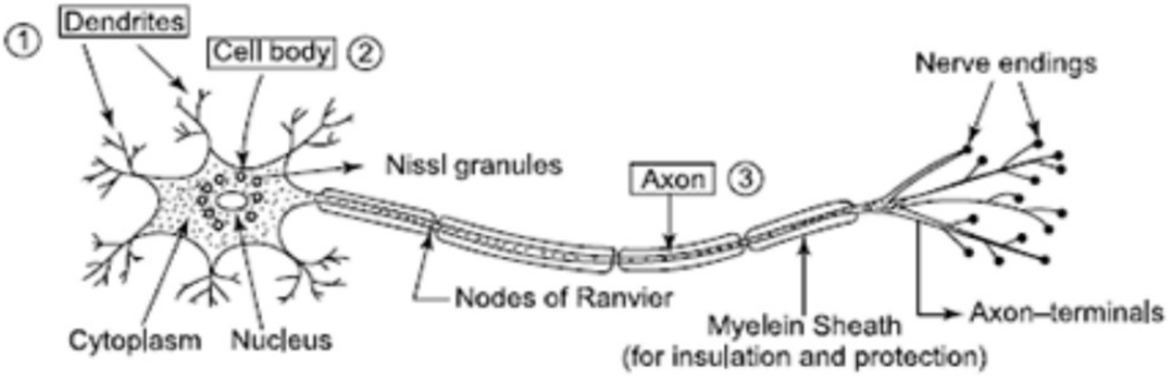

① Dendrites
Cell body ②
Nissl granules
Axon ③
Nerve endings
Nodes of Ranvier
Myelein Sheath (for insulation and protection)
Axon–terminals
Cytoplasm
Nucleus

Figure B.6.9

A neuron (nerve cell)

Function of the Nervous System

All the functions of the nervous system outlined above are carried out because of three basic features of this system:

(i) **Sensory**—The **receptors detect** internal as well as external stimuli, e.g., temperature receptors located in the hand detect a hot object.

(ii) **Integrative**—**Inter-neurons** integrate or **process** the information that is received and make an appropriate decision for final response, e.g., Inter-neurons decide that the hand should be moved away from the hot object to prevent burning.

(iii) **Motor = Effectors respond** to integration decisions, e.g., withdrawal of hand from the hot object

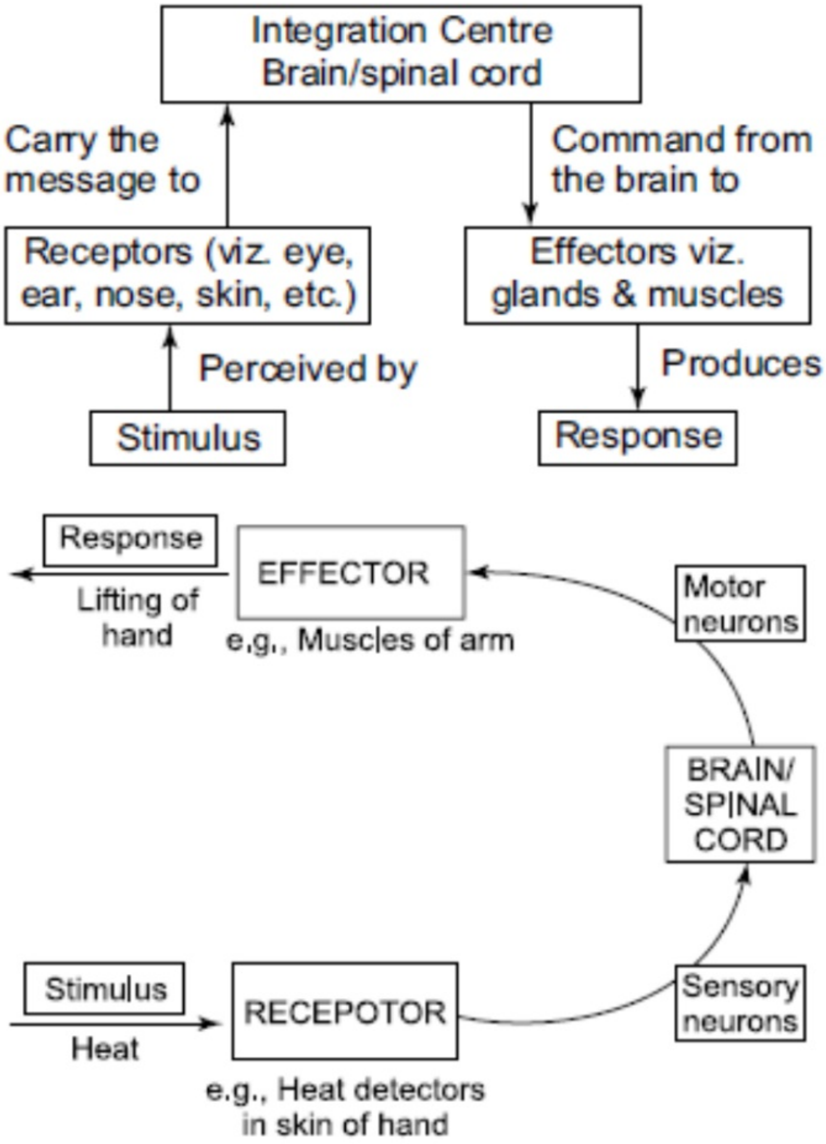

Integration Centre
Brain/spinal cord
Carry the message to
Command from the brain to
Receptors (viz. eye, ear, nose, skin, etc.)
Effectors viz. glands & muscles
Perceived by
Produces
Stimulus
Response
Response
EFFECTOR
Lifting of hand
e.g., Muscles of arm
Motor neurons
BRAIN/ SPINAL CORD
Sensory neurons
Stimulus
Heat
RECEPOTOR
e.g., Heat detectors in skin of hand

Figure B.6.10

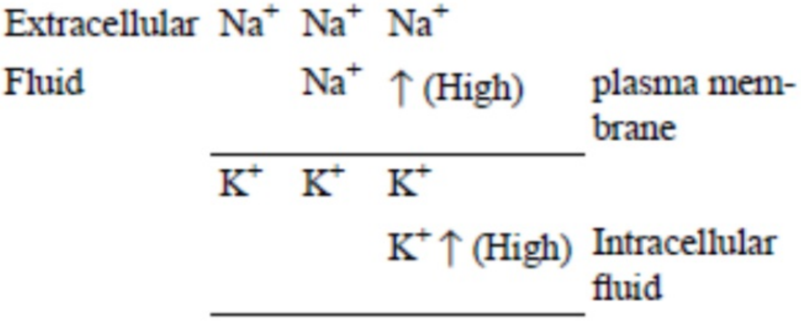
A reflex arc

Electric Signals in Neurons

The transfer of information from receptors to brain or spinal cord and the appropriate response or command to effectors is mediated by **nerve impulses**. Therefore, the generation and conduction of nerve impulses is an essential aspect of nerve physiology. The mechanism involves the following terms:

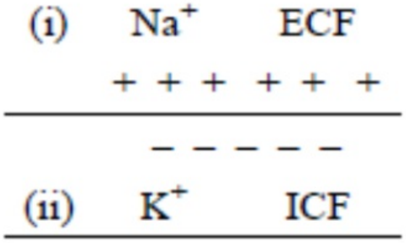
(i) **Resting membrane potential:** It is the membrane potential of a nerve in the resting state, i.e., when a nerve is **not stimulated** or excited. It results from

- **unequal distribution of ions:** The sodium and potassium ions are distributed unequally across the plasma membrane of a nerve cell.



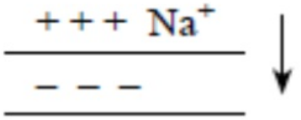
- **Relative permeability of the plasma membrane:** The plasma membrane shows differential permeability to sodium and potassium ions. It is more permeable to K^+.
- **Electrogenic pumps:** They expel three sodium ions from the cytosol for every two potassium ions imported, and thus help in maintaining the resting membrane potential.

These three factors create a difference in electrical charges on either side of the membrane. It is positive outside and negative inside creating a **potential difference** across it. This is known as **resting membrane potential** and it is about -70mv (millivolts) for nervous tissue. Such a membrane is said to be polarised.

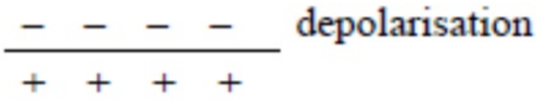


(ii) **Action Potential:** When the nerve fibre is stimulated, the membrane potential reverses its polarity. It is known as action potential. It consists of two phases: Depolarisation and Repolarisation

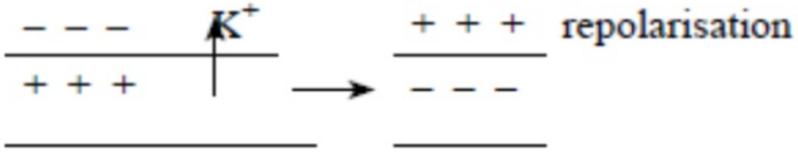
(a) **Depolarisation:** Depolarisation is brought about by the **opening of sodium ion channels**.



This causes reversal of the charge distribution or potential difference, which changes from negative potential (-70m V) to positive potential (+30m V) inside the nerve cell. The potential reaches a peak called "spike potential" or action potential.



(b) **Repolarisation:** When the stimulus is over, the membrane of the nerve fibre returns back to its original state and this phase is called as **repolarisation**. It's brought about by **closure of sodium channels and opening of potassium channels**.



Propagation of Nerve Impulse

The propagation of nerve impulse is explained by the so called "*local circuit theory*". The membrane becomes depolarised at the point of stimulation and hence acts as a "sink", towards which the current flows from the adjacent areas. This results in conduction or passage of nerve impulse. Conduction of impulse is of two types – (i) continuous conduction and (ii) saltatory conduction.

(i) **Continuous conduction:** In this type of impulse propagation, there is step by step depolarisation and repolarisation of each adjacent segment of the plasma membrane. Therefore it is called **continuous conduction**. It occurs in **unmyelinated axons**.

(ii) **Saltatory nerve conduction**: This is a special mode of impulse propagation along **myelinated axons**, in which nerve impulse "leaps" from one node to the other ("Saltatory means leaping").

Transmission across Synapse

Synapse: It is a point or site of communication (or gap) between the plasma membranes of two neurons or between a neuron and an effector cell. If the effector cell is a skeletal muscle fibre, it forms a **neuromuscular junction**.

The mechanism of transmission of nerve impulse across a synapse occurs in the following steps.

(1) The tips of some axon terminals swell into bulb-shaped structures called **synaptic end bulbs** which contain many small membrane-enclosed sacs called **synaptic vesicles** that store a **chemical neurotransmitter**.

(2) **A nerve impulse arrives** at synaptic end bulb of a **pre-synaptic axon** ("pre"= before; synapse, i.e., axon of a neuron which is present **before** synapse).

(3) This causes **exocytosis** of some of the synaptic vesicles, because of increase in calcium ion concentration inside the pre-synaptic neuron, due to the opening of calcium channels.

(4) There is **release of neurotransmitter** molecules in the synaptic cleft.

(5) The neurotransmitter molecules diffuse across the synaptic cleft and **bind to neurotransmitter receptors** present in the plasma membrane of the **post-synaptic neuron**. ("Post" means after, therefore it refers to a neuron present **after** the synapse).

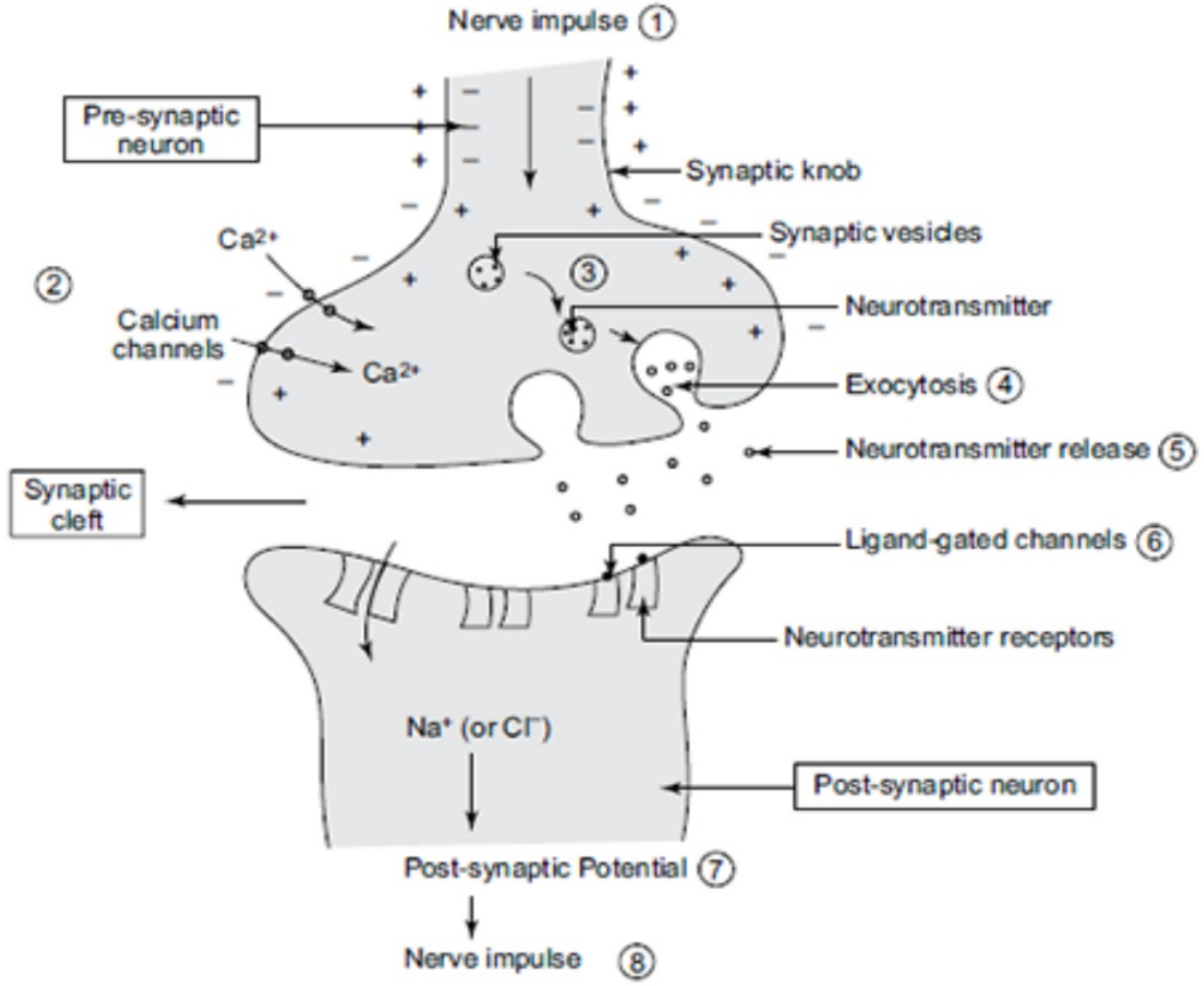

Nerve impulse ①
Pre-synaptic neuron
Synaptic knob
Synaptic vesicles
②
Ca^{2+}
Calcium channels
Ca^{2+}
③
Neurotransmitter
Exocytosis ④
Neurotransmitter release ⑤
Synaptic cleft
Ligand-gated channels ⑥
Neurotransmitter receptors
Na^+ (or Cl^-)
Post-synaptic neuron
Post-synaptic Potential ⑦
Nerve impulse ⑧

Figure B.6.11

Signal transmission across a synapse

(6) This binding leads to the **opening of sodium channels**.

(7) Inflow of sodium ions, causes **depolarisation**. This also causes a change in membrane voltage, called as **post-synaptic potential**. This is **excitatory** in nature therefore also known as **excitatory post-synaptic potential** or EPSP.

(**Note:** If instead of sodium channels, chloride channels open, then it causes inflow of chloride ions resulting in **hyper-polarisation,** i.e., the inside of the membrane becomes **more negative** than the resting membrane potential. This is known as **inhibitory post-synaptic potential** or IPSP).

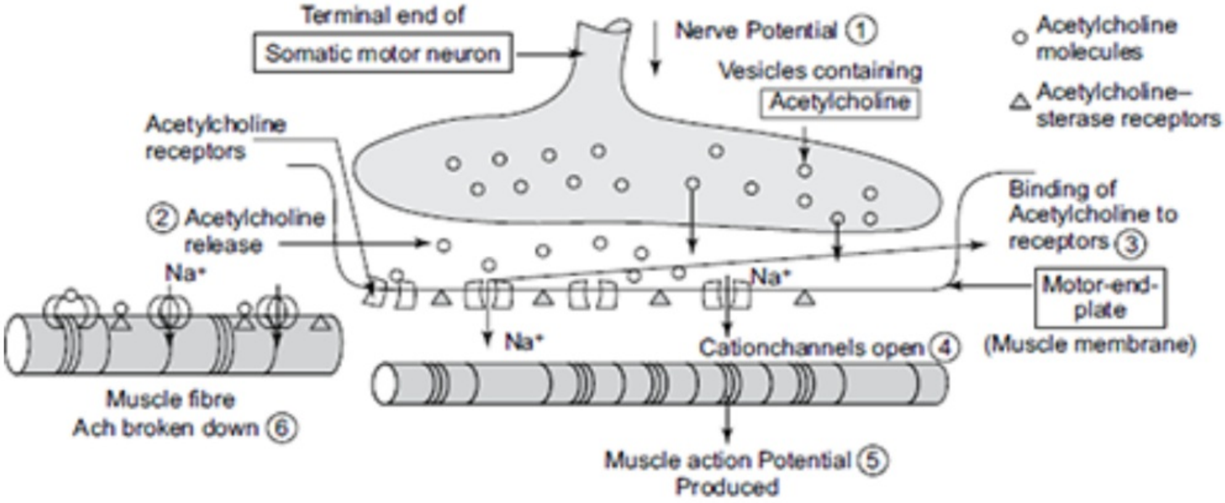
(8) When a depolarising post-synaptic potential reaches sufficiently high or critical levels known as **threshold**, an **action potential** is generated and a nerve impulse passes across the synapse.

(9) After the passage of nerve impulse across the synapse, the neurotransmitter either diffuses away from the site or is taken up again by the synaptic vesicles or undergoes enzymatic degradation (e.g., Acetylcholine is degraded by the enzyme

acetylcholinestrase).

Neuromuscular Junction

The synaptic transmission between an axon terminal of **somatic motor neuron** and plasma membrane of **skeletal muscle fibre**, is called as a **neuromuscular junction**.



Terminal end of
Somatic motor neuron
Nerve Potential ①
Vesicles containing
Acetylcholine
Acetylcholine molecules
Acetylcholine–sterase receptors
Acetylcholine receptors
② Acetylcholine release
Na⁺
Binding of Acetylcholine to receptors ③
Na⁺
Motor-end-plate
(Muscle membrane)
Na⁺
Cationchannels open ④
Muscle fibre
Ach broken down ⑥
Muscle action Potential ⑤ Produced

Figure B.6.12

Neuro-Muscular Junction

The sequences of events occurring in neuromuscular transmission are similar to a synapse except few differences like:

(i) The neurotransmitter released at the junction is **only Acetylcholine,** which is **excitatory** in nature.

(ii) Therefore, the post-synaptic potential is **always excitatory,** therefore, it results in an **action potential** (also known as **end-plate potential**).

(iii) The plasma membrane of skeletal muscle fibre is called **motor end-plate**.

Neurotransmitters

These are a diverse group of chemicals released into synaptic cleft, in response to a nerve impulse. Chemically, they can be proteins, biogenic amines, purines, neurohormones, neuropeptides, etc. Most common neurotransmitters are Acetylcholine, Epinephrine or Nor-epinephrine. **Endorphins** are neuropeptides known for their "feel good" effect while **Dopamine** is active during emotional responses, addictive behaviours and pleasurable experiences and help regulate muscle tone.

Some neurotransmitters are **excitatory** in nature, e.g., epinephrine, glutamate, aspartate; sometimes acetylcholine, e.g., in neuromuscular junction while others are **inhibitory,** e.g., GABA (Gamma-Amino-Butyric-Acid) and glycine.

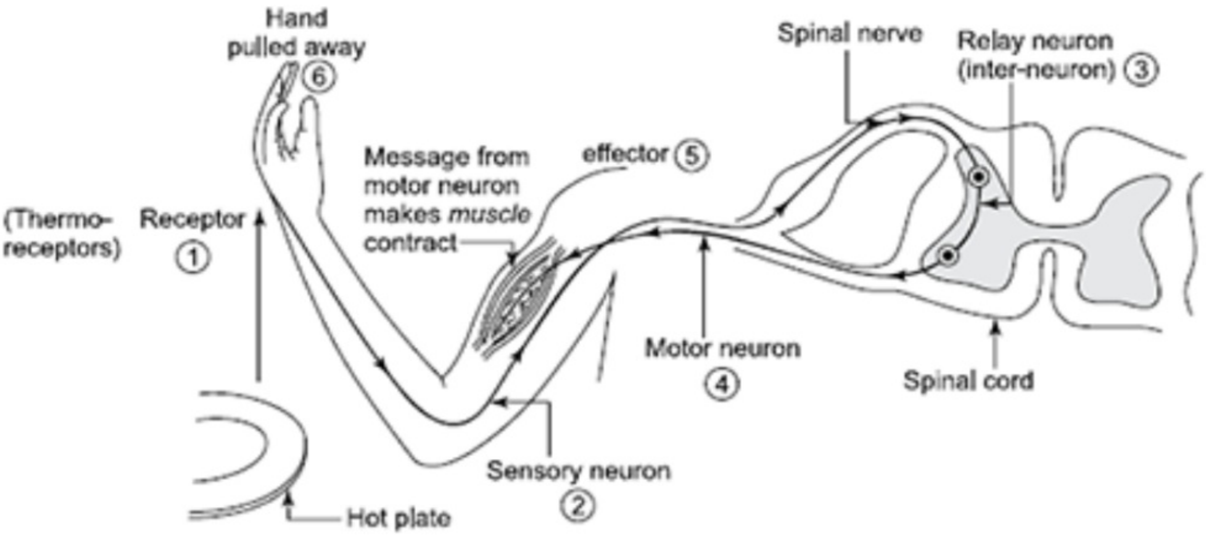
Reflex Action

A reflex action is a **simple, automatic, involuntary and rapid** response to a stimulus, which normally, involves **only the spinal cord** viz. a knee jerk, blinking of eyes, moving our foot away from something sharp or withdrawing our hand on touching a hot object.

Sometimes, instead of the spinal cord, brain is involved in the reflex action. Such reflexes are known as **cerebral** (brain) **reflexes,** e.g., contraction of pupil of the eye in the presence of bright light.

Clinical disorders of Nervous System

(1) *Multiple selerosis* is a disease that causes a progressive destruction of myelin sheath of neurons in the CNS. It is an *auto-immune disorder*.



Hand pulled away ⑥
Spinal nerve
Relay neuron (inter-neuron) ③
Message from motor neuron makes *muscle* contract
effector ⑤
(Thermo- receptors)
Receptor ①
Motor neuron ④
Spinal cord
Sensory neuron ②
Hot plate

Figure B.6.13

(2) *Epilepsy* is short, recurrent, periodic attacks of motor, sensory or psychological malfunction.

(3) *Dementia*—Permanent or progressive general loss of intellectual abilities, including memory.

(4) *Alzheimer disease* is a disease of aged persons (above 65) who lose the ability of reasoning, memory, read, write, talk, eat or walk including care for oneself and become confused, forgetful, disoriented with violent changes in mood.

The major cause of this disease is loss of neurons that liberate acetylcholine (a neurotransmitter). Interestingly, Amitabh Bachchan was suffering from this disease in movie "Black". Many eminent world personalities like American President Ronald Reagen, British Prime Minister Margaret Thatcher were also victims of this debilitating disease.

(5) *Stroke* is caused due to destruction of brain tissue, resulting in paralysis and loss of sensation.

(6) *Parkinson disease* is again a progressive disorder of the CNS that typically affects persons around age of 60. Patients suffer from involuntary skeletal muscle contractions,

resulting in shaking or *tremors,* slow movements, difficulty in writing, walking and even speaking, decreased muscle tone, etc. It is caused due to imbalance of neurotransmitters —too little dopamine and too much acetylcholine.

(7) Spinal cord may be damaged by a tumour, trauma or injury, blood clots, etc. Depending on the location and extent of damage, **paralysis** may occur.

Monoplegia ("mono" = one, "plegia" = blow or strike). It is paralysis of one limb only.

Diplegia ("Di" = two) paralysis of both upper or lower limbs.

Paraplegia ("Para" = beyond) paralysis of both lower limbs.

Hemiplegia ("hemi" = half) paralysis of upper limb, trunk and lower limb on one side of the body.

Quadriplegia ("quad" = four) paralysis of all four limbs.

B.6.10 HUMAN DEFENSE MECHANISM—THE IMMUNE SYSTEM (RESISTANCE TO DISEASE)

The human beings are surrounded by innumerable harmful agents viz. UV rays in sunlight, chemicals, toxins and various pollutants in our environment, including **pathogens**. But, despite these deterrants it is a miracle that they still remain healthy. (well, most of the time!). This might be due to the fact that they are **thick skinned** (literally) and have a strong defense system.

Resistance

The human body is armed with a defense system to ward off the damage or disease. This is known as **resistance**, which is of **two** general types:

(a) Non-specific (Innate) defenses and **(b) Specific resistance.**

(a) **Non-specific defenses** show the following characteristics:

- It forms the first line of defense.
- It is present at birth.
- It shows immediate response.
- It provides general protection against a **wide** range of pathogens.
- The protection is provided by various barriers, such as (i) **mechanical** (skin, mucous membrane, hair, tears, saliva, urine, etc.) and (ii) **chemical** barriers viz. sebum—the acidic film on the skin, **lysozyme** in tears, saliva, etc., **gastric juice** (acid) which destroys bacteria and most toxins in the stomach.

(a) **Specific resistance or Acquired Immunity or Adaptive Immunity:**

This type of immunity is characterised by the following features:

- It develops **on contact** with a **specific** invader.
- It shows slow response.
- It involves activation of **specific lymphocytes** to combat an individual **specific**

pathogen viz. bacteria, virus, toxins, etc.

- It displays two properties: (i) **specificity** for particular foreign molecules—the antigens, and (ii) **memory** for most previously encountered antigens.

Acquired Immunity in turn is of **two** types:

(1) **Humoral Immunity** and (2) **Cell-Mediated Immunity**

(1) In humoral immunity, the body develops circulating **Immunoglobulins** or **Antibodies** which attack and invade the foreign agents. It is directed against **extra cellular antigens.**

(2) Cell-Mediated Immunity is carried out by specialised cells called **'T' lymphocytes** and **macrophages** with **cyto-toxic** properties ("cyto" = cell and "toxic" = harmful). It is directed against **intra-cellular pathogens** viz. viruses, some cancer cells and tissue transplants.

> The 2011 Nobel Prize for Physiology or Medicine was awarded to Bruce Beulter and Jules Hoffmann jointly for their discoveries concerning the activation of innate immunity & the other half to Ralph Steinman for the discovery of the dendritic cell and its role in adaptive immunity.

Lymphocytes

*The cells with the ability to carry out immune responses, when stimulated, are known as **lymphocytes.** These are of two types—'T' lymphocytes and 'B" lymphocytes. They both develop in primary lymphatic organs (red **bone marrow and the thymus**) from multi-potent cells.

'T' lymphocytes develop from pre-'T' cells that migrate from bone marrow into **thymus**, where they mature. They are of four types: (a) Cytotoxic 'T' cells or killer cells (b) Helper 'T'cells (c) Memory cells and (d) Suppressor cells.

'B' lymphocytes develop in the **bone marrow**. They are also of two types (a) Plasma 'B' cells and (b) Memory cells.

Immunity

Immunity is resistance to foreign proteins and invading pathogens. It can be either: (a) **Active immunity** or (b) **Passive immunity**.

(a) Active immunity: In active immunity the lymphocytes are **activated** by antigen present on the surface of the pathogen. It is produced either naturally or artificially. In **natural immunity** the activation takes place during the natural course of an infection, whereas, in **artificial immunity**, the activation occurs by injection of antigens into the body. It is also known as **vaccination**.

(b) Passive immunity: In this type of immunity the individual becomes temporarily immune to an antigen because of exposure to pre-formed antibodies. It is also of two types—natural and artificial. In **natural passive immunity** the antibodies pass naturally from mother to baby through placenta or breast milk, and in **artificial passive immunity** the pre-formed antibodies extracted from one individual are injected into another as '**serum**', e.g., snake bite.

Antigen

The term derives its name from its function as an **anti**body **gen**erator. Therefore, it's a substance which generates an immune response. Chemically it's usually a protein, or nucleic acid, large polysaccharides or large lipoprotein complexes. They have **large molecular weights**, more than 10,000 daltons, with simple, repeating subunits. As a rule, they are **foreign substances**.

Antibodies or Immunoglobulins (Ig)

The antibodies or immunoglobulins show the following characteristics:

(i) These are produced in response to a "foreign substance" acting as an"antigen".

(ii) Chemically, these are glycoproteins—the *globulins.*

(iii) Structurally, they contain four **polypeptide chains**—two **heavy chains** and two **light chains**.

The heavy chains are held together by (-S-S) **disulphide bonds**, which in turn, are also joined to light chains by disulphide linkages.

(iv) It can assume either a T-shape or Y-shape.

(v) Within each heavy and light chains are two distinct regions. The tips called the **Variable regions**, constitute the **antigen-binding site**. The remainder of each heavy and light chain called the **constant region**, is nearly the same in all antibodies of the same class.

(vi) There are *five* classes of immunoglobulin's – IgG (most abundant), IgA, IgM, IgD & IgE.

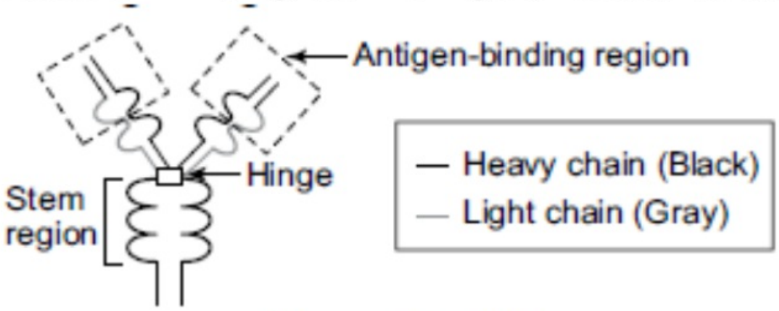


Figure B.6.14(a)

(vii) Antigen and Antibody bind to each other very specifically on a "lock & key" pattern.

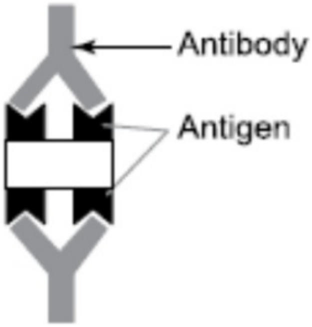


Figure B.6.14(b)

(*Note*: This "Sticking together" of antigen to antibody is known as **agglutination** which stimulates phagocytosis by neutrophils)

Monoclonal Antibodies

Antibodies are produced against a given antigen by plasma cells. However, because an antigen typically has *many* "***epitopes***" (small parts of antigen molecule that triggers immune response), several different clones of plasma cells ***produce different antibodies***. Therefore in order to produce ***monoclonal antibodies*** ("mono" = single), (MAbs), scientists fused 'B' cells with tumour cells, that grows and proliferates endlessly, resulting in a hybrid cell, called as ***hybridoma.*** These cells are long-term sources of large quantities of pure and identical antibodies.

These MAbs are used for diagnosis of pregnancy, allergies, diseases viz. hepatitis, rabies, sexually transmitted diseases, and also for early detection of cancer and metastasis (spreading). These are also useful for measuring levels of drug in a patient's blood or in preparing vaccines to counter act the rejection associated with transplants. These are used either alone or in combination with other drugs to treat cancer because of its advantage of destroying only the tumour tissue and not the healthy tissue (which is a major disadvantage of chemotherapy and radiation therapy) as well as autoimmune diseases and perhaps AIDS also!

Vaccination

Two types of immunological responses are manifested on exposure to an antigen:

(a) **Primary response** and (b) **Secondary response**

(a) **Primary response** shows the following unique features:
  - (i) It is a response following **first or initial exposure** to an antigen.
  - (ii) It is a slow response.
  - (iii) It shows weak potency, there are no antibodies produced initially.
  - (iv) It has a short life (few weeks).
  - (v) It has a lower affinity for antigens.

(b) **Secondary response** is characterised by the following features:

(i) It is a response following a **second or subsequent exposure** to an antigen.
(ii) It is very rapid.
(iii) It is very potent and intense. It forms antibodies for **many months**.
(iv) It has a long life.
(v) It has a higher affinity for the antigen.

The hallmark of this response is **immunological memory. Memory cells** may remain for decades and every new encounter with the same antigen results in the rapid proliferation of these memory cells. Consequently much higher antibody titre is produced causing immediate and rapid response with increased potency and duration.

This also provides the basis for immunisation by vaccination against certain diseases viz. small pox, polio, measles, etc. Here, a weakened or killed microbe (an ***antigen)*** is injected in the form of a vaccine, in multiple doses with periods of several weeks or months between injections causing the 'B' & 'T' cells to activate. Subsequently, when a living pathogen or an infecting microbe is encountered, the body initiates a secondary response, killing it very efficiently.

> English physician, Edward Jenner is widely credited as the pioneer of "small pox" vaccine. He is also known as the "Father of Immunology". The term "vaccination" has originated from the latin word "vaccinia" meaning cowpox.

There are various types of vaccines viz. bacterial (e.g., whooping cough), viral, polysaccharide (e.g., influenza), Toxoid (e.g., diphtheria & tetanus), **Recombinant Antigen** (i.e., hepatitis B), synthetic peptide and **DNA vaccines** and even **"edible" vaccines***!* AIDS vaccine in tomato, HIV-suppressing protein in spinach, human vaccine for hepatitis B in potato, etc. are examples of edible vaccine. BCG vaccine against tuberculosis and Satin vaccine against poliomyelitis are "weakened" or "attenuated" vaccines.

Allergies

On normally encountering a foreign antigen, an immune system manifests a number of responses to combat this challenge. Sometimes, there is an *increased* or *inappropriate* immune response to antigenic challenge known as **hypersensitivity or allergy**.

The agents that induce allergic reaction are called as **allergen***s* viz. certain foods like milk, eggs, shellfish, etc.; antibiotics viz. penicillin, tetracycline, etc., vaccines, venoms (honeybee, wasp, snake), cosmetics, chemicals in plants viz. poison ivy, pollens, dust, iodine-containing dyes, etc.

On re-entry of these allergens into the body to which a person is "sensitilised", one ***produces IgE*** antibodies which ***binds on surface of "mast" cells and basophils*** These cells ***release chemicals like histamine,*** prostaglandins, etc. which are ***carried* by the *blood stream*** to skin or mucous membrane, and produce symptoms of allergy viz. sneezing, sniffing, gasping, running eyes, inflammation of skin in form of dermatitis, eczema, etc.

AIDS

A condition resulting from genetic or developmental defect in the immune system is called as ***primary immunodeficiency***, whereas if it results from exposure to various agents viz. x-radiation, exposure to certain drugs and infections, it is called **secondary or acquired immunodeficiency**.

By far the most common secondary, immunodeficiency is Acquired Immuno Deficiency **Syndrome** or AIDS, which has reached epidemic proportions particularly in Africa and western countries. It was first reported in U.S.A. in 1981 and now worldwide 35–40 million people are currently infected with HIV. In India it was reported in April 1986, from Tamil Nadu but now it has spread to different parts of India. The condition is particularly alarming in North-East States. This is called as secondary immunodeficiency because AIDS virus reduces the natural immunity of the human body and hence patients become prone to many **other** infections or disease. Subsequently, death occurs due to ***secondary infection ,*** as patient's body can't resist the attack of simple pathogens. Hence a person can die even from simple cold. It results from the infection with the ***Human Immunodeficiency Virus 1*** *(HIV-1)**. The patient infected with this experiences a number of secondary infections primarily due to the progressive destruction of immune system. **This infection is very serious. The very cells that are entrusted with the responsibility of attacking the virus are taken over by the virus itself**. The immune system fails because it has very few 'T' cells and ratio of helper 'T' cells to suppressor 'T' cells, normally.

The symptoms, though may develop after many years (even while the virus is actively attacking the immune system) include fever, fatigue, rash, headache, joint pain, sore throat and swollen lymph nodes, sweating, weight loss and severe damage to brain. It's usually transmitted by the blood while sharing syringes used for blood transfusions, via semen and vaginal fluid, during unprotected sex, anal, vaginal or oral sex or in intravenous drug users and also from an infected mother to her child during pregnancy or birth.

[*] **HIV-1 is a retrovirus** (i.e., its genetic information is carried by ***RNA*** instead of DNA).

Autoimmune Diseases ("Auto" meaning "self")

The immune system normally displays recognition of the "self" from "non-self" (or foreign), known as **immunologic tolerance,** i.e., the immune system can recognise its own cells, tissues or chemicals from an outsider (**foreign protein** or the foreign antigen). Hence, it does not produce 'T' or 'B' cells against them. But, **sometimes this sensibility is lost** and it fails to discriminate between its own and foreign antigens. This loss of immunologic tolerance results in autoimmune diseases, where immune response mediated by antibodies is produced against **its own tissues** or antigens.

Some of such diseases are Type-I diabetes mellitus, multiple sclerosis, rheumatoid arthritis, thyroiditis, rheumatoid fever, hemolytic and pernicious anemia and *myasthenia gravis* (the disease which affects our superstar Amitabh Bachchan)

Interferons

These are an extraordinary group of proteins whose **anti-viral** activity led to their discovery almost 50 years ago. Lymphocytes, macrophages and fibroblasts ***infected with viruses produce proteins*** called **interferons** or IFNs.These are released by virus-infected cells and diffuse to uninfected neighbouring cells to induce synthesis of anti-viral proteins. It has other effects too, viz. induce cell differentiation and inhibit *angiogenesis* in various immunoregulatory roles.

IFNs can stop viral replication and therefore prevent the occurrence of diseases. It forms an important defense system against many viral infections viz. chicken pox, genital herpes, rabies, rubella, eye infections, encephalitis and even common cold. There are three types of IFNs—(i) a (alpha), (ii) b (Beta) and (iii) g (gamma). They are also widely used as therapeutic agents for cancer, multiple sclerosis, multiple myelomas, etc.

CHAPTER SEVEN

HEALTH AND HUMAN DISEASES

B.7.1 INTRODUCTION

According to W.H.O. (World Health Organisation), “Health” means a state of physical, mental and social well-being. It is dependent on one’s physical surroundings and economic status. On the other hand, a “disease” is a disorder or discomfort or departure from “health”. This can be due to lack of well-being of either the body or mind or society.

Since disease is a “discomfort” or a disorder, there can be several causes for this uncomfortable condition viz. infection by a virus or bacteria or worm, etc., or malnutrition or poor sanitation or genetic or metabolic defects, etc.

Therefore, human diseases can be broadly classified into (a) **Congenital** Diseases and (b) **Acquired** diseases.

(a) Congenital Diseases are present right from **birth** because of errors in metabolism or developmental process or genes, etc. and,

(b) Acquired Diseases **develop after birth,** i.e., these diseases can be acquired after birth. They are further sub-divided into:

Infectious or Communicable Diseases

These diseases are caused by various **infectious** or pathogenic organisms viz. bacteria, virus, protozoa and fungi. Infectious agents are spread through **air, contaminated food, water, physical contact or vectors,** e.g., smallpox, polio, dengue, cholera, tuberculosis, etc.

Non-infectious or Non-Communicable or Degenerative Diseases

These are caused by **malfunctioning** of some organ or organ-system in the body. e.g, Heart attack, Arthritis, Hypertension, Diabetes mellitus, etc.

Deficiency Diseases

These are caused due to **deficiency** of certain nutrients, minerals or vitamins, e.g., Kwashiorkor, Rickets, Goiter, Xerophthalmia, Beriberi, Scurvy, etc.

Allergies

These diseases are caused due to **hyper sensitivity** of a person to some substances viz. drugs, dust, pollen, etc.

Cancer

This is caused due to **uncontrolled** and uncoordinated growth of normal cells or tissues, e.g., cancer of colon, Leukemia, etc.

Acute Diseases

These diseases last only for a **short duration,** e.g., cold or cough.

Chronic Diseases

These diseases last for **longer duration**, even for a lifetime, e.g., chronic heart disease or blood pressure, etc.

Two **new** types of diseases can be added to this list, which are a “gift” of our so called progress and development. These are listed below.

Diseases caused due to Pollution

This class of diseases is highly varied ranging from simple irritation to more serious respiratory disorders, emphysema, allergies, cancer, etc. (**from air pollution**); to diarrhoea, cholera, etc. (**from water pollution**); to loss of hearing, heart diseases, or hypertension (**from noise pollution**); to skin cancer, and even death (**from nuclear or radiation pollution**); etc.

“Life Style” Diseases

These diseases are truly a by-product of our increasing comfortable, highly competitive and "defective" life style. e.g., lack of walking or sedentary life style results in obesity. This coupled with eating "junk" food and increasing "tension" causes heart diseases, hypertension, etc. Working in call centres or having irregular working hours results in sleeping disorders. Thus, man is paying a "heavy price" to become "modern", successful or more advanced!

A list of communicable diseases is given below in tabular form. All other types of diseases are discussed in appropriate sections.

List of Communicable Diseases

	Disease	**Pathogen**	**Route**
I. Air-borne diseases			
(a) Caused by Viruses	(i) Common cold	Rhinovirus	
	(ii) Influenza or flu	Orthorhinovirus	
	(iii) Measles (Rubella)	Measles (paramyxo virus)	
(b) Caused by Bacteria	(i) Diphtheria	*Corynebacterium diphtheriae*	
	(ii) Pneumonia	*Diplococcus pneumonia*	
	(iii) Tuberculosis	*Mycobacterium tuberculosis*	
	(iv) Whooping Cough	*Hemophilus pertussis*	
II. Water-borne diseases			
(a) Caused by Bacteria	(i) Cholera	*Vibrio cholera*	
	(ii) Bacillary dysentery	*Shigella dysenteriae*	
(b) Caused by Protozoa	(i) Diarrhaoea	*Giardia intestinalis*	
	(ii) Amoebic dysentery or amoebiasis	*Entamoeba histolytica*	
III. Through direct contact			
(a) Caused by Viruses	(i) Small pox*	Variola virus	*Droplets or indirectly through infected objects
	(ii) Chicken pox*	Varicella virus	**Virus in saliva and secretion of nose, saliva, stools contaminated articles
	(iii) Measles (Rubella)	Measles (paramyxo virus)	
	(iv) Mumps**	Mumps virus (paramyxo virus)	

	(v) Herpes	Herpes virus simplex	
(b) Caused by Bacteria	(i) Leprosy	*Mycobacterium leprae*	Long and close contact with infected person
IV. Through contaminated food Cholera, Amoebiasis, Diarrhoea, Dysentery			
(a) Caused by Worms	(i) Taeniasis	*Taenia solium*	Infected measly pork
(b) Caused by Bacteria	(i) Botulism	*Clostridium botulinum*	Poisonous food
V. Through animals or other vectors			
(a) Caused by Viruses	(i) Poliomyelitis	Polio virus*	*Houseflies, fleas (contact, food and water also)
	(ii) Rabies	Rabies virus**	**Bite of mad dog
	(iii) Dengue fever	Dengue virus (arbovirus)***	***Mosquito (*Aedes*) bite
	(iv) Viral encephalitis	Encephalitis virus (arbovirus)****	****Some domestic animals (reservoir) transmitted by mosquito bite
(b) Caused by Bacteria	(i) Plague	*Yersinia pestis*	Rat flea
	(ii) Typhoid	*Salmonella typhi*	Flies (also food, water, faeces and carriers)
(c) Caused by Protozoans	(i) Malaria	*Plasmodium*	Female anopheline mosquito
	(ii) Sleeping sickness (Trypanosomiasis)	*Trypanosoma brucei*	Bite of tsetse fly
	(iii) Kala-azar (or black sickness)	*Leishmania donovani*	Bite of sand fly
Caused by Worms	(i) Filariasis	*Wuchereria bancrofti*	Through mosquito larvae on skin
VI. Sexually transmitted			
(a) Caused by Virus	(i) AIDS*	HTLV-III (retro virus)	Among homosexuals *(also *via blood*)
(b) Caused by Bacteria	(i) Gonorrhoea	Diplococcus (*Neisseria gonorrhoeae*)	
	(ii) Syphilis	*Treponema*	

		pallidium	
(c) Caused by Protozoan	(i) Vaginitis	*Trichomonas vaginalis*	
(d) Caused by Worms	(i) Ancyclostomiasis (or Hookworm disease)	*Ancyclostoma duodenale*	Mostly spread from person to person
	(ii) Ascariasis	*Ascaris lumbricoides*	
	(iii) Enterobiasis (or Pinworm disease)	*Enterobius vermicularis*	

B.7.2 PRINCIPLES OF PREVENTION OR TREATMENT OF DISEASES

Since disease is a "disorder", it can be corrected or prevented; either by:

(1) manipulating the root "**cause" of the disease**, e.g., "infectious" diseases can be prevented by keeping our surroundings and environment clean, or maintaining good hygiene or better sanitation, good ventilation, preventing over-crowding, etc. Similarly, "deficiency" diseases can be checked by providing a healthy balanced nutrition to all.

But, all the above-mentioned methods are only able to **prevent the exposure to a disease**. However, if a person is born with some defective organ or malfunction or the disease has already struck, despite precautions, then the second step has to be undertaken, which is, **prevention of the disease.**

(2) killing or preventing the "cause" of the disease— There are two ways of "preventing" the disease from occurring, one which is present in the body itself, **the immune system** and the other is "**extrinsic**" mechanism, which is operated from the outside, i.e., **the use of medicines or vaccines**.

The Immune System

The immune system of our body is our very own "in-built" mechanism to fight diseases. It is provided with specialised cells ('T' and 'B' lymphocytes) to kill any foreign antigen, which is capable of causing a disease. It springs into action, as soon as it encounters a foreign antigen or infectious agent.

If the immune system manages to **kill** the infection, we don't actually come down with any disease and if it is able to **control** the number of infectious microbes, then the manifestation of disease is **mild**. It is only when these microbes are able to “fool” or evade the immune system, that a person suffers from the disease.

(This system has been dealt in detail in Human Defense Mechanism).

If this “inherent” or “intrinsic” system fails, then the body needs the “extrinsic” mechanism.

The Use of Medicines or Vaccines

Sometimes, the immune system may not be able to prevent the disease from occurring or the disease may be present from birth itself and in that case, appropriate medicines have to be taken viz. antibiotics or anti-viral drugs or other medicines.

These medicines “kill” the disease-causing microbe and also alleviate the symptoms of the disease.

CHAPTER EIGHT

HUMAN GENETICS

B.8.1 BLOOD GROUP INHERITANCE

K. Landsteiner and his students discovered blood groups in human beings (1900–1902) known as ***ABO* blood groups**. A person's blood is classified into one of the four types: A, B, AB or O on the basis of carbohydrate molecules present on the surface of red blood cells (which serve **as *antigens*),** i.e., if RBCs have carbohydrate

'A' on its surface, then the blood group is type 'A', *if*
'B', then it is type 'B'
and if both are present, then it is type 'AB'
and when none are present, it is type 'O'.

The different blood groups can be identified by testing these antigens with different *anti-sera* which result in clumping of blood cells, known **as *agglutination***. If anti-sera match with their corresponding antigen, it results in agglutination.

These blood groups are determined by ***three alleles*** of a single gene: I^A, I^B and I^O **(*an example of multiple alleles*).** The genes I^A and I^B are ***dominant*** but show no dominance over each other, i.e., they are ***co-dominant*** whereas both the genes, i.e., I^A and I^B are dominant over the gene I^O or 'i' therefore gene I^O or 'i' is ***recessive.***

Table B.8.1 systematically lists the various blood groups, their antigens and antibodies and other relevant information.

Table B.8.1

Blood Groups and Possible Transfusions in Various Persons

Blood group	Carries antigen	Carries antibody/antisera	Can donate blood to	Can receive blood from
A	A	Anti-B	A, AB	A and O
B	B	Anti-A	B, AB	B and O
AB	A and B	None	Only AB	**Universal acceptor**
O	None	Anti-A and anti-B	**Universal donor**	Only O

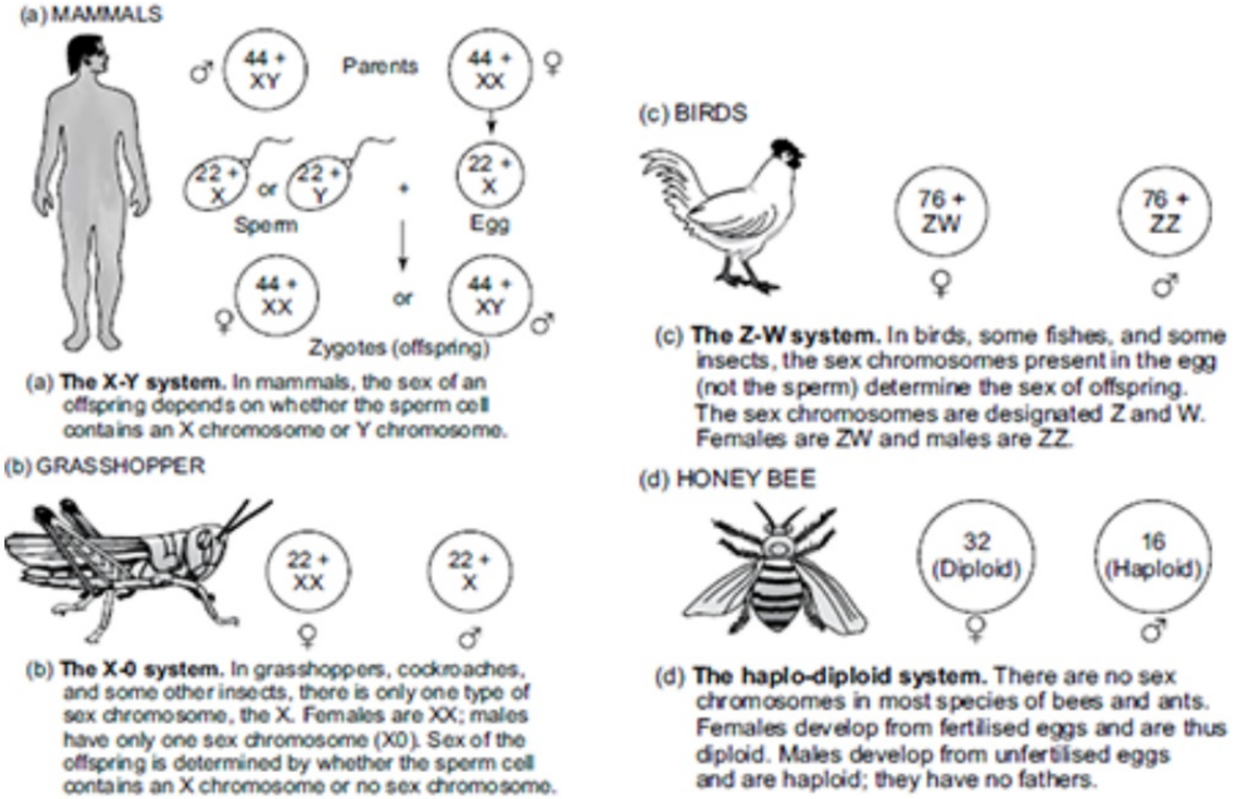
There are several other blood antigens present on the surface of RBCs viz. MN antigens, ***Rhfactor*** (so named because it was first found in rhesus monkeys), etc.

Matching compatible blood groups is critical for safe blood transfusions and pregnancy. These blood group studies have also been very useful in solving problems of disputed parentage.

B.8.2 SEX DETERMINATION IN ANIMALS

The sexual reproduction requires participation of two different sexes—a male and a female. Normally, these two differ from each other in many external and internal features, but the basis for determination of sex is rather simple. The mechanism of sex determination is different in different organisms. However, in most of the cases it has a ***genetic or chromosomal basis,*** e.g., humans, birds, insects, etc., but in some it may be ***environmental cues*** viz. temperature or diet also! In some reptiles viz. turtle *Chrysema picta*, temperature, determines the sex of the offspring. Here, high incubation temperature leads to the development of female offsprings.

There are two types of chromosomes in organisms—***autosomes*** and ***sex chromosomes***. *Sex chromosomes are designated as X & Y*; It is the sex chromosomes that are important for sex determination. If the ***same*** sex chromosomes are present in pair, the sex is said to be ***homogametic*** (e.g., XX) and if they are ***dissimilar***, it is said to be ***heterogametic*** (e.g., XY). Sex determination in different animals is summarised in the Fig. B.8.1.



(a) **The X-Y system.** In mammals, the sex of an offspring depends on whether the sperm cell contains an X chromosome or Y chromosome.

(b) **The X-0 system.** In grasshoppers, cockroaches, and some other insects, there is only one type of sex chromosome, the X. Females are XX; males have only one sex chromosome (X0). Sex of the offspring is determined by whether the sperm cell contains an X chromosome or no sex chromosome.

(c) **The Z-W system.** In birds, some fishes, and some insects, the sex chromosomes present in the egg (not the sperm) determine the sex of offspring. The sex chromosomes are designated Z and W. Females are ZW and males are ZZ.

(d) **The haplo-diploid system.** There are no sex chromosomes in most species of bees and ants. Females develop from fertilised eggs and are thus diploid. Males develop from unfertilised eggs and are haploid; they have no fathers.

Figure B.8.1

Examples of chromosomal system of sex determination

In *Drosophila*, sex is determined by the ratio of X chromosomes to set of autosomes (*X:A*). If

X: A < 0.5, the fly develops as a male

X: A > 1.0, the fly develops as a female and

0.5 < X: A < 1.0, the fly develops as an intersex.

Note: In 1990, a British research team identified a gene on the Y chromosome required for the development of testes in ***humans***. They named the gene ***SRY*****,** for **S**ex-determining **R**egion of **Y**. In the absence of SRY, the gonads develop into ovaries because this is the gene required for the development of testes.

B.8.3 GENES AND CANCER

Cancer refers to a set of diseases in which cells somehow escape the control mechanisms that normally keep a check on their growth or signal pathways or receptors. The sources of mutations can be several, ranging from environmental influences viz. UV radiation or chemical carcinogens viz. food additives, preservatives, pesticides, insecticides, etc. or X-rays and other high energy radiation to certain cancer-causing viruses or even tobacco smoke and air pollutants.

The breakthrough in understanding cancer came in 1911, when **Peyton Rous,** an American pathologist, discovered a virus that causes cancer in chickens. Since then, scientists have discovered a number of ***tumor viruses*** that cause cancer in various animals, including humans, e.g.,

Epstein-Barr virus – Burkitt’s lymphoma
Papilloma virus – Cancer of cervix
HTLV-1 – a type of adult leukemia
*Retro virus – HIV, (AIDS)
Corona virus – Severe Acute Respiratory Syndrome (SARS)

Research on these tumor viruses led to the discovery of cancer-causing genes called ***oncogenes*** (derived from the Greek word “*onco*” meaning tumor) in certain retroviruses. Subsequently, close relatives of these oncogenes were also found in the genomes of animals and humans. The *unmutated* or ***normal*** version of these genes is called ***proto-oncogenes*** which codes for proteins that stimulates normal cell growth and division. These genes can regulate growth factors or receptors or signal molecules during cell cycle. Now, if these normal or proto-oncogenes undergo genetic changes, i.e., ***mutations*,** they are transformed into ***oncogenes*.** This disrupts the cell cycle and therefore can lead to cancer.

However, there are also some cellular genes that normally function to *inhibit* cell division. Such genes are called ***tumour-suppressor genes*** because these prevent uncontrolled cell growth. As, transformation of proto-oncogenes to oncogenes can cause cancer by mutation, similarly mutation of tumour-suppressor genes can also lead to malignant growth, e.g., *Retinol blastoma* (Cancer of retinal layer of the eye) and *Nephro blastoma* (Wilm’s tumour).

This does not mean that cancer can be caused ***only by genes***, but it can also ***arise spontaneously*** **by *non-inheritable* causes**.

B.8.4 DNA-FINGER PRINTING

The role of finger-prints in forensic cases is undisputed. Based on this knowledge, that similar to fingerprints, ***each individual also has a unique genome*** with the same nucleotide sequences, scientists developed a technique, known as ***DNA fingerprinting.*** **No two individuals, except for identical twins, have the same genome**. Recent evidences have demonstrated that the human genome contains large families of DNA polymorphisms of many different types viz. VNTRs. These are short DNA sequences present as tandem repeats of variable length at several chromosomal locations, which can be used to produce ***DNA fingerprints***.

DNA fingerprinting provides a powerful forensic tool, to nail the culprits even from minute amounts of blood, semen, hair bulbs or other cells. The DNA is extracted from these cells amplified by PCR (Polymerase Chain Reaction) and then suitably analysed.

Although this technique is widely used in all cases of questionable identity but they have proven specially effective in ***solving paternity and forensic*** **cases,** e.g., recently it has been used in identification of terrorists of 26/11 Mumbai attack, in Nithari murder case, in solving paternity issue of Mr. N.D. Tewari, etc.

DNA fingerprints These are specific banding patterns on southern blots of genomic DNA cleaved with a specific restriction enzyme and hybridised to appropriate DNA probes.

B.8.5 CLONING

The word ***clone*** comes from the Greek word “Klon” meaning “twig”. It refers to a group of **genetically identical** cells or tissues or organisms. The cloning of plants and animals was first attempted eighty years ago (during 1950s) and since then many plants viz. potato, carrot, sugarcane, mango, citrus, roses, grasses, etc. and few animals, particularly lower animals, have been cloned because they commonly reproduce asexually.

Among the higher animals, clones are not found naturally and artificial attempts have not been very successful. Such experiments were conducted on frogs by Robert Briggs and Thomas King in 1950s and by John Gurdon in 1970s and who reported that the transplanted nucleus was often able to support normal development of the egg into a tadpole. But, such experiments were far and few.

Until in 1997, when a Scottish group of researchers shook the world by storm, announcing the birth of "***Dolly***", a lamb cloned from an adult sheep by nuclear transplantation from a differentiated cell. Later in 2003, at age of six, however, Dolly suffered from a lung disease and died. Since then scientists have cloned numerous other mammals' viz. mice, cats (CC-Carbon Copy), cows, horses, mules, pigs and dogs.

The successful cloning of numerous mammals raised hopes of cloning of humans too! Although, it also ignited unprecedented ethical issues. The controversial experiments on human cloning were carried out by several labs around the world. In 2001, a research group in Massachusetts observed a few early cell divisions in such an experiment. A few years later, South Korean researches reported cloning embryos to an early stage called the blastocyst stage.

Although the heated debate about its relevance still rages but research is also going on in this direction. Who knows one day we might have clones of Sachin Tendulkar or Anna Hazare or A.P.J. Abdul Kalam or even Osama Bin Laden!

B.8.6 PRACTICAL APPLICATIONS OF DNA TECHNOLOGY

1. ***Use of Recombinant DNA technology to identify human genes*****,** particularly the defective genes that cause human diseases viz. Huntington's disease, cystic fibrosis, etc.
2. ***Molecular diagnosis of human diseases***—The mutant genes responsible for several inherited human diseases can be accurately diagnosed by screening genomic DNAs and results of these tests can then be used by genetic counselors to inform about the risks.
3. ***Human Gene Therapy***—This involves the *addition of a normal* (wild-type) *copy* of a gene to the genome of an individual who carries defective copy of the gene, e.g. ***somatic cell gene therapy*** for patients with adenosine deaminase-deficient severe combined immunodeficiency disease (AdA$^-$ SCID).
4. ***Transgenic Plants and Animals*** (already discussed in detail)

In 1985**,** ***Kary Mullis*** developed a technique called **the *polymerase chain reaction*** (PCR) that produces millions of copies of DNA from a minute amount of a selected DNA sequence for molecular analysis.

B.8.7 HUMAN GENOME PROJECT

As the recombinant DNA, gene cloning and DNA sequencing technologies improved in the 1970s and early 1980s, the scientists became more and more bold and ambitious and they began to think about the possibility of sequencing the entire human genome which is about 3 ¥ 10^9 nucleotide pairs at an estimated cost of $ 3 billion. This gave birth to the **Human Genome Project in** 1990 with **Dr. James, D. Watson** as its first director. As of now, the complete nucleotide sequences of the genomes of 599 viruses, viroids, 205 plasmids, 185 organelles viz. chloroplast and mitochondria, 32 true bacteria, 7 archaea, a fungus, a plant, a worm and a fly have already been determined. Incidentally, in 1995, ***the entire genome sequence of the first bacterium***, *Haemophilus influenza* was reported. This project stimulated similar mapping and sequencing projects on the genomes of several other organisms viz. *E.*coli (bacterium), *S. cerevisiae* (yeast), *D. melanogaster* (fruitfly), *A. thaliana* (a plant) and *C.* elegans (a worm).

The Human Genome Project, a giant leap in the field of genomics was also a very formidable task. Soon, the scientists realised the enormity of this task, which involved mapping of at least 1,00,000 genes and sequencing an estimated 3 billion nucleotide pairs. This necessitated a coordinated as well as an international effort and hence ***International Human Genome Organisation*** **(HGO)** was established. This involves an international, publically funded consortium of scientists at Universities and research institutions with 20 large sequencing centres in six countries like USA, Germany, France, Japan, England and Switzerland with China joining later, plus a number of other labs working on small projects.

Initially, the project envisaged (i) to map all human genes (ii) to construct a physical map of the entire human genome, and (iii) to determine the nucleotide sequence of all the 24 human chromosomes. But, soon the project became very ambitious with the competition hotting up every day.

Dr. Craig Venter*,** who is often considered to be synonymous with this project, because of his enormous contribution to this field, set up an institute, ***The Genomic Research **(TIGR)** in Rockville, Maryland. He later (1998) teamed up with Perkin Elmer Inc. of Norwalk, Connecticut, to form a new private company, ***Celera Genomics*** for funding and commercial exploitation of this research. Venter stunned the genomics community by announcing the sequencing of human genome in just 3 years! His proposal was based on two key developments:

(1) A sequencing strategy called ***whole-genome shotgun sequencing****;* and

(2) The development of faster, fully automated sequencing machine.

In October, 1998, ***Francis Collins*** and colleagues, ***another key player in the race to***

sequence human genome and Director of the ***Human Genome Project*** **(HGP)** announced the completion of the project by 2003—two years earlier than originally planned! They proposed a ***working draft of human*** **genome** with ***at least 90% sequenced with 99% accuracy by 2001.***

This "healthy" competition hastened the progress of both the groups and they achieved their initial goals much ahead of schedule.

On February 15, 2001, the public International Human Genome Sequencing Consortium (IHGSC) published their ***first draft of the sequence of the human genome*** **in *Nature*** (covering *~92%* of the sequence of the genome with 150,000 gaps). On February 16, 2001, a day later, the private Celera Genomics group published their first draft in *Science* covering (*~95%*) of the sequence of euchromatic DNA. Since then, both the groups have not looked back and the race goes on!

Both the studies, however, pointed out the following salient features:

1. ***The small number of genes in the human genome*** *(~30,000)*, although based on the approximate ratio of the size of a typical gene (~3 ¥ 10^4 bp) to the size of human genome (3 ¥ 10^9 bp), it was earlier estimated that there might be 1,00,000 genes in human. This is ***because 50% of the genome comprises of non-coding sequence (or "junk" DNA) and only less than 5% accounts for coding sequences***.
2. ***Proteomes*** **(**or full set of proteins) coded by ***human genome are very complex***.
3. ***Exons*** make up only 1.1% of the genome whereas ***introns*** make up 24% and 75% of the genome is intergenic.

The initial draft of the human genome is far from complete and concerted efforts since then by both the groups have led to the near completion of *Human Genome Project in 2003*. ***Although it's still incomplete with 308 euchromatic gaps and heterochromatic*** **g**enome is yet to be deciphered!

- IHGSC reported the completion of ***euchromatic sequence*** in October, 2004 with only **341 gaps** (as against 1,50,000 gaps reported in the first draft), with 308 euchromatic and 33 heterochromatic gaps.
- The total number of estimated ***protein coding genes are also reduced to 20,000 – 25,000*** *with* 19,599 *confirmed genes* (equal to total number of genes of tiny round worm-C*oenorhabditis elegans*).
- ***Completion of DNA sequencing of chromosome 1*** (largest among human chromosomes) was *reported in May, 2006*. This chromosome comprises nearly 8% of all human genetic information and is associated with over 350 human diseases including cancer, Parkinson's disease, Alzhheimer's disease, etc.

Exons—are segments of DNA that are transcribed into mRNA and then translated into proteins.

Introns—Portion of mRNA that is removed by enzymes before the mature

RNA is translated into proteins.

B.8.8 STEM CELL CULTURE

Stem cells are in the news, because it offers umpteen possibilities to all sorts of patients, particularly to victims of illness viz. Parkinson's disease, diabetes, arthritis, burn victims, etc. A stem cell has two salient features:

(1) It's capable of seemingly **endless reproduction**, division after division, producing descendants just like itself and

(2) It's capable of **producing cells that are committed to differentiate into special cell types** viz. muscle fibres, lymphocytes, neurons or bone cells (because these are **embryonic** cells). Because of these two very unique and special features, stem cells may have the potential for manifold **therapeutic uses,** e.g.,
   (i) to regenerate worn-out tissues
   (ii) to replace lost organs or body parts
   (iii) to correct brain or spinal cord injuries and
   (iv) to alleviate biochemical defects.

These "dreams" have turned into "reality" for several animals, e.g., stems cells derived from mouse embryos can form neuronal support cells compensating for a biochemical defect. Similarly, they also can form neurons that partially restore spinal cord function in rats with spinal cord injury.

However, for humans it's still in its infancy and more of a "fiction" rather than "reality". But, there's experimental evidence that it might work, offering hope to accident victims, patients suffering from several debilitating illness viz. Parkinson's disease, severe arthritis, paraplegics, burn victims, etc.

Although this technique is highly promising but it also raises many moral questions. The ethical issue is on procurement of these stem cells, that is, from embryos or adult body tissue. Can embryonic life be sacrificed for making an adult life better? These and several other questions have generated a vigorous debate on its usage among politicians, religious leaders, journalists and even entrepreneurs.

Recently in 2011, a group of stem cell researchers have been able to direct embryonic and induced human stem cells to become "***astrocytes***"—the most common cells of the human nervous system in a lab dish.

B.8.9 HUMAN GENETIC DISORDERS

Genetic disorders can occur either due to change in chromosome number or structure or mutations. Some of these genetic disorders are listed below.

Name of the disorder	Cause	Symptoms
I. On the basis of change in chromosome structure		
1. Cri-du-chat Syndrome	Deletion of whole or part of the short arm of chromosome 5	Infant's cry like the mewing of a cat, moon like face
II. On the basis of change in chromosome number		
1. Down's syndrome (Mongolism)	Trisomy of chromosome 21	Mentally and physically retarded, round face with broad skull
2. Edward's syndrome	Trisomy of chromosome 18	Mental retardation with several congenital malformations
3. Klinefilter's Syndrome	Additional X-Chromosome (XXY)	Sterile (men) with Mental retardation
4. Turner's syndrome	Lack of X-chromosome (XO)	Phenotypically females with rudimentary sex organs and mammary glands
5. Patau Syndrome	Trisomy of chromosome 13	Cleft lip, deafness, mental retardation
III. Gene mutation		
1. Albinism	Recessive gene which blocks conversion of amino acid tyrosine to melanin	Lack of pigment in the skin, hair and iris of the eyes
2. Cystic fibrosis	Recessive autosomal gene in homozygous condition	Increased susceptibility of lung infection, abnormal pancreatic function
3. Fabry's disease	Recessive X-linked (sex-linked) gene which blocks metabolism of glycosphingolipids	Lipids as crystals deposit on the walls of blood vessels of heart, kidneys, eyes, causing shooting pain
4. Hemophilia	Sex-linked recessive gene causing defective synthesis of clotting factor	Haemorrhage
5. Huntington's disease	Dominant autosomal gene	Develops at the late age of 30-40 years and slowly leads to loss of control on the movement of limbs

6. Muscular dystrophy (Duchenne type)	Sex-linked recessive gene during childhood	Progressive muscle weakness and atrophy
7. Phenylketonuria (PKU)	Recessive autosomal gene in homozygous condition	Brain damage leading to mental retardation
8. Sickle cell anaemia	Recessive autosomal gene in homozygous condition resulting in abnormal haemoglobin	Inability to carry oxygen by blood
9. Tay-sachs disease	Recessive autosomal gene after 8–9 months	Degeneration of cerebral function leading to epilepsy, paralysis or even blindness
10. Thalassemia (Cooley’s anaemia)	Recessive gene in homozygous condition	Severe anaemia
11. Lesch-Nyhan Syndrome	Sex-linked (X-linked) recessive trait	Development of involuntary movements, mental retardation
12. Marfan’s Syndrome	Autosomal dominant	Abnormalities of the eye, cardiovascular and skeletal system

CHAPTER NINE

HUMAN EVOLUTION

Indeed, man occupies the loftiest pinnacle of the evolutionary tree and is considered to be a “paragon” of animals. But the story of “our” origin is still clouded with many unanswered questions, because of scarcity of human fossils and that the excavation work is time-consuming and demanding. Despite the “bumpy” road, the understanding of the journey of human evolution is very fascinating and exciting as well as very exhaustive too! Hence, its **phylogeny** has been summarised with its salient features with respect to geological time scale below. Surprisingly modern man **didn’t arise from monkeys** as is popularly believed but from a **shrew-like insectivore** (one which feeds on insects) and is a **product of primate arboreal (tree-dwelling) adventure**.

Some Interesting Facts about Human Evolution

1. Indians belong to Indo-Malayan Race.
2. Our genetic footprints tell us that we have *African* roots.
3. Humans occupy one of the branches in the phylogenetic tree.

HOLOCENE 10,000–30,000 years ago	*Homo sapiens sapiens* (***Cro-Magnon man with various geographical races)*** Early humans (pre-historic), were widely distributed in Europe, Asia, Africa and India. Later they diverged into Europe. **Closest to modern man**, 180cm in height (tall) with large skull, broad face, rounded forehead, **prominent chin, cranial capacity 1600cc, swift footed**, use of stone tools as well as of ***bone*** (Aurignacian industry), **Paleolithic art in caves**, use of animal hide as clothing.
[PLEISTOCENE] (2–3 million years ago)	*Homo sapiens neanderthalensis* Its fossils were first discovered from Neander Valley in Germany,: known as **Neanderthal Man, short** and stocky body, **heavily built** with outwardly curved thigh bones, skull bones thick, forehead low and slanting, **eye-brow ridges heavy** with a **cranial capacity of 1450cc (roughly equal to that of modern man*)***. Culturally more evolved, practiced rituals, burial of dead, skilful hunter, and used

	variety of stone tools.
	Homo erectus - (Pithecanthropus) (Java man), *Sinanthropus* (Peking man) Later became extinct, discovered by **Eugene Dubois** from Java. 5ft. tall, 70 kg wt., **could stand erect**, shorter forearm, longer hind legs, low forehead, chin absent, good hunters, lived in small groups in caves, but most importantly made use of “**fire**” for hunting, defense and cooking (Acheulian and Mousterian culture).
	Homo habilis The **“handy” man (the tool maker)** discovered by **Jonathan Leakey** from Olduwan Gorge in East Africa developed Olduwan technology.
[PLIOCENE] (~5–8 million years ago)	*Australopithecus* **First ape-man**, known as “**Southern Ape**”, connecting link between apes and man. First fully **bi-pedal** (“b_i” means two, “pedal” means feet) hominids, with small brain, short stature, head balanced on neck. Discovered by husband and wife team of **Louis and Mary Leakey**.
[MIOCENE] (~15–17 million years ago) Late	*Ramapithecus*/Kenyapithecus*** Discovered from **Sivalik hills* in India (**from Kenya in Africa). Both were more “**hominids**” (**man-like**) rather than Pongids (ape-like)
Middle (~ 20 million years ago)	*Dryopithecus* First discovered from Africa, with a **blend of monkey & ape characteristics**, probably represents a **common ancestor stage to great apes and man**. Semi-erect posture, had arms and legs of equal length. Skull more specialised than old world monkeys.
Early (~ 25 million years ago)	*Aegyptopithecus* Known as **“Dawn Ape**”. “Most primitive ape” yet; discovered from Fayum in Egypt.
[OLIGOCENE] (~30–35 million years ago)	*Parapithecus*, Propliopithecus*** *found from rocks of Egypt, little squirrel in size, **gave rise to gibbons of today.
[EOCENE] (~50–55 million years ago)	Fossil lemurs, tarsiers & monkeys **(Primates)**
[PALEOCENE] (~65–70 million years ago)	**Insectivore Ancestor** Tiny, quadraped (“quadra”–four; “ped”–feet), arboreal

B.9.1 SPECIATION

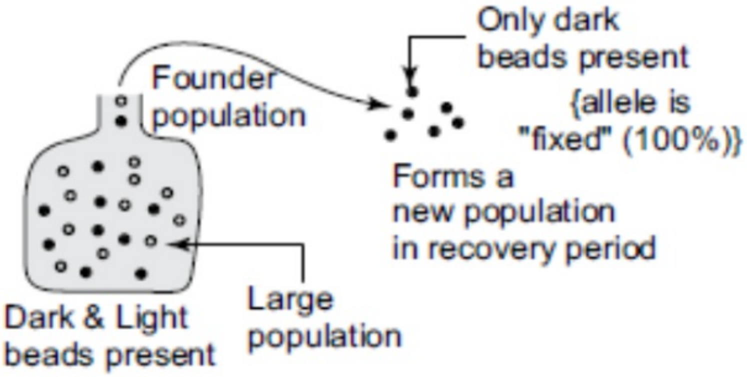
The term species is very confusing and conveys different meanings to different biologists. For a long time, species was considered as an artificial grouping, a “man-made” concept, without any real existence. But, **Linnaeus** gave it a scientific meaning. Still, the term is highly ambiguous. For example; it can be an aggregate of similar looking individuals to a morphologist or a population of organisms living optimally in an area or niche (see glossary) to an ecologist or a group of genetically similar individuals to a geneticist and so on. Therefore, a scientific definition was the need of the day. **Dobzhansky** and **Mayr** defined species as **populations of similar organisms which inter-breed, i.e., produce fertile offsprings (Biological species).** Americans, Europeans, Africans and Indians **all** belong to the same species, i.e., *Homo sapiens*, because although they might be very different looking, with different behaviours, customs, habits, external features, etc. and might be separated by long distances too, but still they can cross-breed, when brought together. Thus, they form one group or **one population** of inter-breeding individuals and hence belong to the **same** species. On the other hand, tigers, leopards, cheetah, panther, etc. all look very similar to each other and are present in the same jungle, but since they cannot mate or breed with each other, therefore they form **different** species. Similarly a crow and a sparrow might be present on the same branch of a tree, but belong to different species.

The process of formation of new species from the ancestral or pre-existing ones is known as **speciation**. It occurs either by splitting of species (**divergence**) or by accumulation of gradual changes with time in pre-existing species (**transformation**).

Speciation can be speculated to occur either gradually or suddenly by the following mechanism. In the sudden type of speciation, the pre-existing species or population undergoes **mutation**, to form a new species. Whereas, in the gradual type of speciation, the population of a species gets separated by **physical or geographical barriers,** such as tall mountains, rivers, large oceans, forests, etc. These barriers split the population into two or more sub-populations, which is known as **isolation**. The two sub-populations are exposed to **different set of environmental conditions**. For example, population A may be exposed to dry conditions, whereas population B may be adapted to wet conditions. Therefore, both the populations are subjected to independent **selection pressure** with respect to its own environment, and may also undergo **genetic drift**. This causes **divergence** between the populations by accumulation of **variations.** If the divergence occurs for several generations (1000s of years), ultimately the two populations become very different from each other, so that they are **unable to inter-breed or exchange genes**. This leads to **reproductive isolation** and finally formation of a **new species**.

B.9.2 GENETIC DRIFT

It is a **random, change in gene frequency**, occurring in **small** populations so that one allele gets “fixed” (reaches 100% frequency) and the other gets “eliminated” (*reaches 0% frequency*), **purely by chance**. It is not related to usefulness of a gene, **consequently a useful allele may be eliminated, purely by chance, and a harmful allele may get “fixed” in the population**. This is characteristic of lemming populations in arctic areas, or small island population, where a population may suddenly **crash** due to severe cold or disease or some other reason. This is also known as **bottle-neck phenomenon** or **Founder’s Principle.**


Founder population
Only dark beads present
{allele is "fixed" (100%)}
Forms a new population in recovery period
Dark & Light beads present
Large population

Note: Light beads are eliminated (0%)

Figure B.9.1

CHAPTER TEN

ANIMAL WELFARE

Animals have been associated with the human beings since the very beginning of their evolution, from the days since he began his journey towards becoming a modern man. They were used as food by hunters, as companions and workers by agriculturists, as gods by modern man and so on.

Animal Husbandry is a branch of agriculture that deals with the study of feeding, breeding, care and utilisation of economically important animals viz. cattle (cows, bull or oxen), buffaloes, goats, sheep, pigs, camels, poultry, etc.

B.10.1 CATTLE

The word "cattle" is derived from the Latin word "capitale" meaning wealth or property. In India, cattle are next to land in use for farmers. Earlier, it included all domestic animals, but presently this word is used for "*Bovines*".

The generic name for humped cattle (cow) is *Bos indicus*. It is adapted to drier regions of the country viz. Gujarat and Rajasthan.

Uses

Cows are classified into three **types** or breeds depending upon their uses:

(i) Drought breeds, (ii) Dairy or Milch breeds and (iii) Dual-purpose breeds

(i) Drought breeds:

- Their meat is tough but give **little milk**.
- Therefore used as "beasts of burden" for various agricultural practices viz. tilling, irrigation and carting.

    - Small and marginal farmers use these breeds.

(ii) Dairy or milch breeds:
  - They have large and spacious digestive system, therefore more the food they consume, more **milk** is produced.
  - Used for milk production.

(iii) Dual-purpose breeds:
  - They provide **milk** as well as help in **agricultural practices**.
  - Hence, preferred by farmers.

Besides milk, cattle also provide manure and domestic fuel in the form of dung and their hides and skins are in great demand abroad and therefore exported.

Breeds

There are 26 breeds of cattle in India, some of them are:

(a) **Indigenous breeds of cow**
  (i) Red Sindhi
  (ii) Sahiwal
  (iii) Gir (found in Gir forest of Gujarat)

(b) **Exotic breeds of cow**
  (i) Jersey (native of U.S.A.)
  (ii) Holstein Friesian ("Holland")
  (iii) Brown Swiss (Switzerland)

(c) **Improved cross breeds of cow**
  (i) Karan Swiss (Brown Swiss x Sahiwal)
  (ii) Karan Fries (Holstein Friesan x Thaparkar)
  (iii) Frieswal Fries (Holstein Friesan x Sahiwal)

India ranks first amongst all countries in the world, possessing the largest number of cattle and buffaloes. According to 2011 livestock census, there are 205 million cattle and 84 million buffaloes, accounting for one sixth of world's population, but the per capita availability of milk is low (only 144g/day as opposed to the standard level of 210g/day), because of poor breed of cattle. Punjab, Rajasthan, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Gujarat are the Indian states rich in good breeds of cattle.

Diseases

1. Foot and mouth disease
2. Bovine Spongiform Encephalopathy (BSE)* or **"mad" cow disease**.

B.10.2 BUFFALOES

It is commonly called Indian water buffalo with the generic name *Bubalus bubalis.* It is well adapted to wet areas and river beds. It is primarily of two types:

(i) The swamp buffalo and (ii) The river buffalo

(i) **The swamp buffalo**
  - Present in marshy lands
  - Found in Malaya, Singapore, Thailand, Indonesia, Philippines, Southern China, etc.
  - Weighs 300–600 kg
  - Yields **small** quantities of **milk** and primarily used as **draught animals**.

(ii) **The river buffalo**
  - Present in riverine areas
  - Found in India, Pakistan, Bangladesh, Nepal and Sri Lanka. In India, found in Kerala, Bengal, Andhra Pradesh and Tamil Nadu.
  - Weighs 450–800 kg
  - Mainly **milch animals** yielding 1400–300 kg of milk during 300 days of lactation period.

Uses

Dairy industry in country is mainly buffalo-oriented, contributing ~ 55% of total milk production because buffaloes yield **more and nutritionally richer milk**.

1. **Buffalo milk** is commercially more usable than cow milk because it is **rich** in proteins, minerals, vitamins and **fats** whereas **low in cholesterol**, sodium, potassium and **water content**. Therefore, it's more dense and white, aptly suitable as whiteners, for manufacture of fat-based products viz. butter, ghee, khoya, etc. and protein concentrates viz. casseinates.
2. Buffalo **meat** is also popular in India (because ban on cow slaughter does not extend to buffaloes). It is of higher lysine content, with more muscle fibres and low fat.
3. Buffalo **horns** are used in making various articles viz. combs, buttons, spoons, forks, knife handles and wall decorations.
4. **Hide** is processed to yield leather.
5. **Hair** is useful for making brushes.

[*] The outbreak of this disease in England made headlines in 1990s and recently in Germany and other European countries.

Breeds of Buffaloes

Indigenous

(i) *Murrah*æfrom Haryana and Punjab with short and tightly curved horns, massive body.
(ii) *Mehsana*æfrom Gujarat—cross between Murrah and Surti; good for heavy work.
(iii) *Surti*æalso from Gujarat with sickle shaped horns. High milk yielding, rich in fat.
(iv) Jaffarbadi, and
(v) *Nilli*æ*Ravi Bhadwari*

Some Common Diseases of Cattle

1. Foot and Mouth disease (caused by virus)
2. Rinderpest (cattle plague) (caused by virus)
3. Cow pox (caused by Vaccinia virus)
4. Anthrax (caused by *Anthrax bacillus*)
5. Liver rot (caused by *Fasciola hepatica*)
6. Measly beef (caused by *Taenia saginata*)

(1) Dr. V. Kurien , who passed away in september 2012, is known as the "Architect of India's Modern Dairy Industry" and is Father of **White Revolution** (huge increase in milk production). He is the founder chairman of NDBB and implemented the world's largest dairy development programme æ the "***Operation Flood*** ".

Some centres associated with improvement in breeding of cattle:
(a) Indian Veterinary Research Institute (IVRI) at Izatnagar.
(b) NDDB (National Dairy Development Board)
(c) NDDI; Karnal (National Dairy Development Institute).

B.10.3 POULTRY

The word, "poultry" has originated from a French word "poult" meaning chicken (the young one of common domestic fowl), but this term includes ducks, geese, turkeys, guinea-fowls, pigeons, pheasants, quail, ostriches and other game birds.

Uses

(1) The poultry industry with its production in the form of **eggs and meat** is of

particular importance in providing a **balanced and protein-rich**(protein is of animal source and cheap) **diet**for the human population.

(2) Moreover they are also efficient **converters**of agricultural by-products and wastes into high-quality meat.

(3) The feathers are used in pillows, for decorative purposes, etc.

(4) They also produce manure.

According to statistics, there are 206 million chickens and 9.0 million ducks in India, (5th largest in the world), although sadly the per capita or year consumption is again very low compared to the world figures.

Breeds

I. Indigenous or Desi

(i) Aseel* (high yield of meat and good egg layer)
(ii) Kadaknath
(iii) Bursa, and
(iv) Chattisgarh

***Varieties**

(a) Peela (golden red)
(b) Yakub (Black & red)
(c) Nurie (White), and
(d) Kajal (Black)

**These breeds are: (i) hardy with natural immunity against common diseases; (ii) Small sized; (iii) Slow growing; (iv) lay fewer and small-sized eggs (60 eggs/yr) .

II. Exotic breeds

(i) White Leghorn
  (a) most prolific egg layer
  (b) small body size (2.7kg)
  (c) produces long, white eggs.
(ii) Rhode Island Red
(iii) White and black Minorcha
(iv) Plymouth Rock
(v) Light Sussex
(vi) New Hampshire

III. Cross-breeds

(i) Astro white—Australorp male X White Leghorn (female)

(ii) HH-260
(iii) IBL-80
(iv) B-77 & (v) IIS-82

These breeds

(i) lay more eggs (200 eggs/yr) and are large sized
(ii) yield more meat (~2.3kg of feed for 1 kg meat)
(iii) consume less feed.

Some Common Diseases of Chicken

1. Ranikhet disease (pathogen—virus)
2. Marck's disease (pathogen—virus)
3. Fowl plague (pathogen—virus)
4. Fowl pox (Avian diphtheria) (pathogen– virus)
5. Fowl typhoid *(Salmonella gallinarum)*
6. Avian influenza or flu (A. virus)*

*It's most highly pathogenic strain **(H5N1),** has spread through Asia, Europe, Middle-East and Africa, responsible for **pandemics** and is **adapted to both humans and birds**.

1. Huge growth in egg production in India is called **silver revolution.**
2. The Central Poultry Breeding Farms are located in Bombay, Bhubaneswar, Chandigarh and Hassarghatta and are engaged in scientific poultry breeding programme for developing fast-growing broilers and high egg-yielding hybrids.
3. Vegetarian eggs: Hens are capable of laying eggs without fertilisation and the eggs thus obtained are infertile. Such eggs are known as *vegetarian eggs*.

Breed Improvement

Breed improvement can be achieved either by **cross-breeding or artificial insemination or embryo transfer**.

A cross between indigenous breed of cow (*Thaparkar*) and exotic breed of bull (*Holstein-Friesian* from Holland), has resulted in improved breed of cows with greater yield of milk, known as *Karan-Fries*. Similarly crosses between Sahiwal (indigenous) X Brown Swiss (exotic) and Sahiwal & Holstein-Friesian have produced *Karan Swiss & Frieswal* respectively.

Among cattle, the indigenous breed *Brahman* (with better heat tolerance and resistance to diseases) has been used to develop new breeds, viz. *Bradford* by crossing it with

Hereford or well established *Brangus* (Brahman X Angus). The cross-breeding between the Pakistan Sahiwal & European Jersey produces improved varieties with increased heat tolerance, resistance to ticks and high level of milk and butter fat.

There are numerous such examples of cross-breeds, e.g., Sunandini cow in Kerala (Brown Swiss X Jersey X Holstein).

Some of the Diseases Transmitted to Human Beings

SARS, Avian Flu, etc.

B.10.4 FISH

In country like India, where the intake of meat and milk is low, fish assumes special importance as a supplement to ill-balanced diet rich in cereals. It helps to correct protein deficiency, one of the world's most serious mal-nutritional problem.

Fisheries

Fisheries primarily started as **capture fisheries** in natural waters such as seas, rivers, lakes, ponds, estuaries, etc. and **Culture fisheries** or **fish culture** is a recent addition.

Fish production includes **fin fish**, *i.e.*, true fishes and **shell fishes** such as prawns, mollusks, echinoderms, etc., It is called **water agriculture** or **fish farming**.

Three types of fisheries can be recognised.

1. Marine fisheries
2. Fresh water fisheries and
3. Brackish water fisheries

Fresh water fisheries and brackish water fisheries are collectively called **inland fisheries**.

Few facts about Indian Fisheries (include both capture and culture)

1. Total fish production in India—7th position in world
2. Marine fish production in India—10th position in world
3. Aquaculture production in India—2nd in South East Asian countries
4. Fish industry contribution—Rs. 400 crores annually as foreign exchange
5. Annual fish production—3.5 million tones
6. Central Inland Fisheries Research Institute (CIFRI) at Barrackpore, West Bengal
7. Central Marine Fisheries Research Institute (CMFRI) at Ernaculum, Cochin, Kerela

Uses

(a) Fish Gulch, sardines, salmon
(b) Liver oil of cod, tuna
(c) Fish meal for pigs, poultry, cattle, etc.
(d) Fish protein in preparation of ice-creams, pharmaceuticals, paints, varnishes, cosmetics, etc.
(e) Fish flour
(f) Fish fertilisers for coffee, tea and tobacco plants
(g) Fish skin, etc.

Integrated Fish Culture

When fish culture is practiced along with some agricultural crop such as paddy, banana and coconut to give higher yield, it is known as integrated fish culture.

Composite Fish Culture (Polyculture of Fish)

Fish production by culturing a single species in a pond is called **monoculture**, but if several species of fish are stocked together in a pond, with different feeding habits, it is called **composite fish farming** or **polyculture of fishes.**

Experiments have shown that Indian major carps, i.e., Catla, rohu and mrigal; when stocked along with three species of exotic carps (i.e., silver carp, grass carp and common carp.; all the three species are transplanted from China), the yield goes up 8–9 times, as compared to monoculture.

Induced Breeding

Chaudhuri and Alikunhi in 1957, used pituitary extracts, as source of gonadotropic hormones (FSH and LH) to achieve artificial breeding in carps. This process is called Induced breeding by **hypophysation**. This technique of inducing spawning in fishes led to **blue revolution** through fish culture.

In recent years due to problems in using pituitary extract, synthetic **inducing agents** containing hormones were developed. These are **ovaprim, ovatide** and **nova**.

"Hapas" - These are small cloth tanks made of coarse or mosquito curtain cloth, also used for hatching and fixed in a larger tank on bamboos.

Exotic Fishes

1. The Gourami (*Osphronemus goramy*) is native to Indonesia, introduced in Calcutta.
2. Tench (*Tinca tinca*) from England and introduced in Ootacamund Lake.
3. The Crucian carp (*Carassius carassius*) native of Central Europe, introduced in Ootacamund Lake.
4. *Tilapia mossambica* from Bangkok
5. *Hypopthalmichthys molitrix* from Japan

Some Common Diseases of Fish

1. **Ich/Ick/White Spot Disease** caused by protozoa *Ichthyophthirius multifilis*
2. **Dropsy**—Virus/bacteria *Pseudomonas fluorescens*
3. **Fin rot**—bacteria
4. **Columnaris** or **Mouth fungus**—Bacteria *Chondrococcus columnaris*
5. **Gill Disease**—Bacteria, fungi and parasites
6. * **Hexamita**—Protozoa *Hexamita*

Often confused with **Hole in the Head/Head and Lateral Line Erosion** (HLLE) which is caused by nutritional deficiency of one or more vitamins viz. Vitamin C, D, calcium and phosphorus.

B.10.5 BEE KEEPING

The practice of bee keeping to obtain honey, bee's wax, etc. is called apiculture.

How is nectar changed into honey?
Nectar containing sucrose, a sugar, is collected from the flowers and is then converted into dextrose and levulose in the **honeysac** by the action of enzyme invertase. After regurgitation, the treated nectar finally changes into honey.

Uses

Apiculture provides us the following useful products: honey, wax, propolis, royal jelly and bee venom.

1. **Honey:** Honey is a sweet, viscous edible fluid containing sugars (20–40 per cent), water or moisture (60–80 per cent), minerals (0.22–0.3 per cent), vitamins (0.2–0.5 per cent), amino acids, enzymes and pollen. It has lot of medicinal value.

2. **Bee wax:** This wax is used by human beings for several purposes such as manufacturing of cosmetics, cold creams, shaving creams, polishes, candles, ointments, lipsticks, lubricants, in modelling work, etc.
3. **Propolis:** These substances are used in repairing and fastening of comb.
4. **Poison:** It is used in manufacturing of certain Ayurvedic and Homeopathic medicines.

Honey Bee Varieties

Both indigenous and exotic varieties of honey bees are used for commercial production of honey in India.

A. Indigenous Varieties of Honey Bees

1. *Apis cerana indica F.* (Indian bee)
2. *Apis dorsata F. (Rock bee)*
3. *Apris florae F.* (Little bee)

B. Exotic Varieties of Honey Bees

1. *Apis mellifera* (European or Italian bee)
2. *Apis adamsoni* (South African bee)

Some Interesting Facts about Honey Bee

(i) **Combs**: These are small, hexagonal compartments made by workers with the wax.

(ii) Bees are called **polymorphic species**, due to existence of several morphological forms, called **castes**. There are following three types of castes in the colony of a bee:

  (a) **Queen: It is a fertile diploid female.** The size of the body of queen is much larger than other castes of bees of the colony, because of very well developed ovaries. They mate, lay eggs, eat proteinaceous food and often do not forage or defend the colony.

  During first 2 to 3 days, all larvae of bee are fed on a special proteinaceous food, called "**Royal jelly**"or **bee bread** (mixture of honey and pollen grain).

  (b) **Drone:** It is a haploid, fertile male. Males are **larger than workers** and are quite noisy and **eat voraciously.**

  (c) **Worker:** (40,000–100,000) Worker is a diploid, sterile female. They are **the smallest** but are the **most active** members of the colony; they have almost all responsibilities on their shoulder.

(iii) **Swarming:** The process of leaving off the colony by the queen with some old drones and workers towards the end of spring or early summer to form a new colony, is known as swarming.

(iv) **Nuptial or marriage flight:**The second swarm is led by 7-day old **virgin queen**, followed by the drones. Then, one of the drones copulates with queen in the sky and fertilises. The drone dies during cop-ulation.This is called as nuptial or marriage flight.

(v) **International Bee Research Association (IBRA)** is located in London.

(iv) Helping behavior exists between members of a social group, viz. honey bee. It is called **altruism** which means self-sacrifice.

> Forager bees communicate about the location of the foraging grounds with their colony mates, in the form of **round-dance** and **waggle-dance**. For decoding the meaning of these dances, an Austrian Zoologist **Karl von Frisch** (1886–1982) took 20 years of research and got Nobel Prize in 1973 for his discovery.

Diseases of Honey Bee

Honey bees are commonly infected by viruses, bacteria, fungi and protozoa. For example, the bacterium *Bacillus apisceptious* infects blood of bee causing septicemia. **Brood foul** disease takes place by Schizomycetes (fungi). **Nosema disease** and **amoeba disease** are caused by protozoan pathogens *Nosema apis* and *Vahlkampfia mellifica*, respectively.

GLOSSARY

Action Potential: An electric signal that propagates along the membrane of a neuron or muscle fiber; A rapid change in membrane potential that involves depolarisation followed by repolarisation.

Active transport: The movement of a substance into or out of a cell across the cell membrane against a concentration gradient which requires the expenditure of energy.

Adaptive Radiation: Evolution of new forms in several different and divergent directions from the common ancestor.

Adenosine Triphosphate (ATP): A compound containing three phosphate groups carrying two high energy bonds; the source of high energy phosphate for energy requiring reactions in cells.

Adolescence: Period between childhood and puberty (sexual maturity)

Allergen: An antigen that evokes a hypersensitivity reaction

Alveoli (singular: Alveolus): Small air sacs of the lungs through the walls of which gaseous exchange takes place between blood and air

Amphibious: Organism which is capable of or spends part of its time living in water and part on land.

Amnesia: Lack or loss of memory

Anabolism: Chemical reactions in which simpler substances are combined to form more complex substances resulting in the storage of energy, the production of new cellular material and growth.

Analgesia: Absence of the sensation of pain

Analogous: Similar in function or appearance but not in origin or development

Aneuploid: A polyploidy with some of the chromosomes of one set missing, so that the chromosome number is not an exact multiple of the haploid number.

Anoxia: Literally no oxygen in the tissues

Antibiotic: A substance, synthesised by micro-organisms. The term usually refers to substances of medical importance, e.g., penicillin, streptomycin, terramycin, neomycin, etc.

Antibody: A protein produced in response to the presence of some foreign substance in the blood or tissues.

Anticoagulant: A substance that can delay, suppress, or prevent the clotting of blood.

Antigen: A foreign substance, usually protein in nature, which elicits the formation of specific antibodies within an organism.

Apnea: Temporary cessation of breathing

Arboreal: Organisms that spend most or all of their lives among the branches of trees.

Artery: A blood vessel that carries blood away from the heart.

Asphyxia: Suffocation, cessation of breathing

Atrophy: Wasting away or decrease in size of a part, due to a failure, lack of nutrition, or lack of use.

Autosomes: Chromosomes other than the sex-chromosomes, i.e., chromosomes not concerned with sex-inheritance.

Bacteriophage: Virus which infects and may kill bacteria.

Basal bodies: Cylinder-shaped cytoplasmic organelles found at the anterior end of flagellated plant cells from which the flagella arise. Structurally they are identical to the centrioles.

Basal metabolism: Energy expenditure of the body under conditions of complete rest; usually determined by measuring the amount of oxygen required and the amount of heat given off.

Benthos: The flora and fauna on the bottom of oceans and lakes.

Berry: A simple fleshy fruit that includes a fleshy ovary wall and one or more carpels and seeds; fruits of grapes, tomatoes and banana.

Biological clock: Means by which activities of plants or animals are adapted to the regularly recurring changes in the external physical conditions, and perhaps to changes in internal milieu (environment) as well.

Biomass: The total weight of all the organisms in a particular habitat.

Biosphere: The entire zone of air, land and water at the surface of the earth that is occupied by living things.

Blood serum: The fluid that exudes when blood clots; it is plasma minus clotting agents.

Blood sugar: The amount of glucose in circulating blood; average normal level is 100 mg/100 ml.

Blue baby: The appearance produced by some congenital heart defects.

Buffer: A substance that tends to preserve the original hydrogen ion concentration (pH), which otherwise would change by adding acids or bases.

Capillary: A microscopic blood vessel located between an arteriole and venule through which materials are exchanged between blood and interstitial fluid.

Catabolism: Chemical reactions by which complex substances are converted, within living cells, into simpler compounds with the release of energy.

Chemosynthesis: Synthesis of food (organic substances) by some autotrophic bacteria, obtaining energy for the process from the oxidation of inorganic substances.

Chromosomes: Self-duplicating rod-shaped or threadlike bodies present in all plant and animal cells, especially observed during cell division stages, which stain intensely with basic dyes as they contain most of the cellular DNA, i.e., *genes* borne in a linear order.

Chyle: Lymph containing globules of emulsified fat, found in lymphatic vessels during digestion.

Chyme: The partially digested food after leaving the stomach.

Cilia (singular: cilium): Slender, hairlike cell prolongations (appendages) primarily meant for locomotion. Structurally they are similar to flagella, but differ in the general pattern of their beat cycles. Flagella and sperm tails demonstrate a continuous propagation of relatively planar bends, whereas cilia have a three-dimensional effective recovery stroke.

Cloaca: A chamber with common opening in which terminal portions of digestive, urinary and genital systems open.

Clone: A population of genetically identical cells.

Commensalism: A relationship between two species in which one is benefitted and the other neither harmed nor benefitted by existing together.

Condom: A sheath for the penis worn during coitus to prevent conception or infection.

Conjugation: The fusion of similar gametes (*isogametes*) or the act of temporary union of two individuals resulting in the transfer of nuclear material from one cell to the other, as occurs in various algae, fungi and protozoans.

Conjunctiva: The thin membrane that lines the eyelids and the exposed surface of the eyeball.

Consumers: Organisms (heterotrophy) incapable of synthesising their own food; obtain their nourishment by consuming the producers or other consumers.

Convergent or Parallel Evolution: Similarity between distantly related groups, because of common habit or habitat.

Convulsion: A violent, uncontrolled muscle spasm, or a series of them; sometimes repeated rapidly and accompanied by unconsciousness.

Cretin: Victim of severe congenital thyroid deficiency, causing physical and mental retardation.

Dehydration: Excessive loss of water from the tissues of the body.

Dead air: A volume of air in the breathing system that is not available for gas exchange and that is not moved by normal breathing.

Decomposers: Organisms that obtain their nutrients by feeding upon dead organisms, breaking them down into simpler substances and, in doing so, making their nutrients available, for the producers.

Dendron (dendrite): A nerve fibre, typically branched, which conducts a nerve impulse toward the cell body.

Diabetes insipidus: A disease characterised by elimination of very large amounts of urine accompanied by chills and extreme thirst.

Diabetes mellitus: The inability to utilise carbohydrates and fats due to insufficient insulin, eventually resulting in the excretion of glucose in the urine.

Dialysis: The process of separating smaller particles from large particles by the difference in their rates of diffusion.

Diaphragm: Any partition that separates one area from another especially, the dome-shaped skeletal muscle between the thoracic and abdominal cavities.

Diastole: The phase of relaxation or dilation of heart muscle (particularly ventricles), during cardiac cycle.

Differential leucocyte count (DLC): The estimation of the relative proportions of the different leucocyte cells in the blood.

Diffusion: The movement of materials from areas of higher concentration to areas of lower concentration.

Dominant gene: A gene that suppresses the expression of another allelic gene (gene controlling the same character and located at the same position on a homologous chromosome).

Effector: A muscle or gland innervated by somatic or autonomic motor neuron; it responds to the stimulus.

Electrocardiogram (ECG): A recording of the electric current produced by the contraction of heart (cardiac) muscles.

Electroencephalogram (EEG): A recording of the electric currents developed in the brain.

Electron microscope (EM): A microscope using beams of electrons to allow small specimens to be examined.

Enamel: The white, compact, and very hard substance that covers and protects the dentin of the crown of a tooth.

Endocrine: A gland that secretes hormones into the blood; a ductless gland.

Enzyme: A substance that accelerates chemical reactions; a biological catalyst, usually a protein.

Epidemiology: The study of the occurrence and distribution of disease in human populations.

Epididymis: Complexly coiled tube next to the testis where sperms are stored.

Epigenesis: A theory of development of living organisms proposed by Wolff in 1759 which maintained that the embryo did not exist preformed in the egg but developed out of formless material.

Epiglottis: The lidlike structure that covers the opening to the larynx.

Fertilisation: The process of fusion of a male gamete (sperm, spermatozoid, or antherozoid) with an egg resulting in the formation of a zygote.

Fibrinogen: A soluble protein of the blood from which the insoluble protein called fibrin, is produced; essential to blood coagulation.

Flagella (singular: flagellum): A slender, whiplike cell prolongation which functions as an organelle of locomotion in both prokaryotes and eukaryote, e.g., bacteria, algae, fungi, and sex cells (sperms) of higher plants and animals.

Gamete: A haploid reproductive or sex cell taking part in sexual fusion forming the diploid zygote (e.g., egg/ovum and the sperm/spermatozoid or antherozoid).

Gene: The unit of heredity—a segment of DNA molecule in all living organisms and a segment of RNA in some RNA-viruses (virus that do not have DNA). It is also referred to as *cistron*—a unit of function, thereby controlling heredity.

Gigantism: An abnormal overgrowth, especially in height, due to oversecretion of growth hormone secreted by the anterior pituitary gland.

Glycolipids: A kind of lipid molecule to which a sugar molecule is bound (Greek *glykos,* 'sweet' and lipid).

Glycolysis: Anaerobic process of breaking down of glucose into two molecules of pyruvic acid that occurs in the cytoplasm.

Glycoprotein: A conjugated protein (protein with a non-amino acid component) with a sugar as its component (Greek *glykos*, 'sweet' or sugar).

Gray matter: Areas in the central nervous system and ganglia containing neuronal cell bodies, dendrites, unmyelinated axons, axon terminals and neuroglia. Nissl bodies impart a gray color.

Haemoglobin: The iron-containing, red, respiratory pigment of vertebrates and a few invertebrates that transports oxygen.

Haploid: An organism, or structure having a single set of unpaired chromosomes.

Hepatitis: Acute or chronic viral inflammation of the liver.

Heterozygous: An individual in which two members of a pair or a series of pairs of genes are different, e.g., Rr, Tt, Ww, and therefore, producing dissimilar gametes with reference to these particular genes.

Hibernatlon: The dormant state of decreased metabolism in which certain animals pass the winter.

Homeostasis: The tendency to maintain stability in the internal environment despite changes in the external environment.

Homologous: Structures of various animals which have similarity in basic structure and development.

Homozygous: An individual in which two members of a pair or series of pairs of genes are alike, such as RR, rr, tt, etc. Such individuals, consequently, produce identical gametes with respect to these particular genes.

Host: An organism, a plant, an animal, or even a microbe like a bacterium on which another organism feeds (parasite).

Hydrolysis: Breakdown of complex molecules into simpler ones making use of water (Greek: *hydro* -water, *lysis*-loosening or breakdown).

Hydrophilic: Compounds that have a strong affinity for water and, therefore, are soluble in it.

Hymen: A fold of mucous membrane which normally partially covers the entrance to the vagina.

Immunogenicity: Ability of an antigen to provoke an immune response.

Incubation period: The interval between exposure to a disease and its appearance.

Inflammation: The reactions of tissues to injury, pain, increased temperature, redness, and accumulation of white blood cells.

Inheritance (Heredity): The process whereby characteristics of parents are transferred to offspring (through genes).

Intrauterine device (IUD): A semi-permanent contraceptive device consisting of plastic or metal of variable shape inserted into the uterus.

In vitro: Literally, in glass; outside the living body and in an artificial environment viz. laboratory or test tube.

In vivo: In the living body

Ischemia: Lack of sufficient blood to a body part due to obstruction or constriction of a blood vessel.

Jaundice: A condition characterised by yellowness of the skin, whites of eyes, mucous membranes and body fluids.

Kilocalorie (Cal or kcal): A large calorie equal to 1000 small calories, defined as amount of heat required to raise the temperature 1 kg of water from 15 to 16 C.

Kwashiorkor: A childhood disease resulting from a deficiency of dietary protein.

Lactation: The process by which milk secretion in the breasts is initiated and maintained and milk is delivered to the suckling infant.

Lacteal: An intestinal lymph vessel that takes up fat from digested food, pertaining to milk.

Leukemia: Blood cancer characterised by a rapid and abnormal increase in the number of white blood cells, plus many immature cells in the blood.

Lipids: Oily or waxy substances that are insoluble in water but soluble in organic solvents like benzene, acetone, petroleum, ether, etc., e.g., all kinds of oils and waxes, vegetable and desi ghee, cholesterol and other steroids.

Macromolecule: A high molecular weight molecule composed of smaller units or monomers linked together, e.g., proteins (composed of amino acids), DNA and RNA (composed of nucleotides), starch, cellulose, etc.

Melocyte: A cell undergoing meiosis.

Menarche: The onset of menstruation, the first period.

Meninges: The membranes enclosing the brain and the spinal cord.

Mesosomes: Special structures formed by the in foldings of the bacterial membrane increasing its surface area. These mesosomes may also function as binding sites for the duplicated DNA molecules so that the two molecules do not get included in one cell during cell division since spindles do not occur in bacteria.

Metabolism: Sum total of physical and chemical reactions by which an organism maintains itself and carries out the activities characteristic of the living state.

Metastasis: The transfer of disease from one organ or body part to another that is not connected to it; an important event in cancer.

Mitotic spindle: A characteristic arrangement of microtubules, shaped like a spindle, during mitotic division of a cell nucleus to align and move chromosomes at metaphase and anaphase.

Monosomic: A diploid organism, plant or animal, with one of the chromosomes of a particular pair missing (2n-1), e.g., human beings (man or woman) have 23 pairs (46) of chromosomes. If a person has 45 chromosomes, he or she will be a monosomic.

Monozygotic: Derived from a single (same) zygote, e.g., identical twins, (mono-single or one).

Mutation: A sudden, discrete and discontinuous change in the genome (genetic makeup) of an organism which is heritable.

Mutualism: A–association between two or more species in which both benefit.

Myocardial infarction: A heart attack, death of a portion of a heart muscle caused by blockage of a coronary artery.

Myxedema: A condition which results from a deficiency of thyroxine in adults; characterised by low metabolic rate.

NADP: (*Nicotinamide adenine dinucleotide phosphate*) A co-enzyme that functions as an electron acceptor in various reactions of photosynthesis and respiration being itself reduced in the process ($NADPH+H^+$ or $NADPH_2$). The reduced co-enzyme ($NADPH+H^+$) readily donates the electrons and protons accepted and thus functions as a strong reductant (a compound that reduces another compound).

Nanometer (nm): A unit of length, one thousandth of a micrometer (10^{-3} mm) one millionth 1/1000,000) of a millimeter (10^{-6} mm), or one billionth of a metre (10^{-9} m).

Necrosis: A pathological type of cell death due to disease, injury or lack of blood supply.

Neoplasm: A new and abnormal formation of tissue as a cancer or tumour.

Nerve impulse: Sum total of physical and chemical events that are associated with the transmission of a signal distally along the length of an axon (nerve fibre).

Niche: An ecological environment in which a species can survive and reproduce optimally.

Nitrification: The oxidation of ammonia and ammonium salts into nitrates by the activity of some bacteria. The bacteria involved are thus, called nitrifying bacteria.

Nucleic acids: Phosphorus-containing macro-molecules (large, organic molecules) present in the nucleus and cytoplasm, as deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Also present in some cell organelles like chloroplasts and mitochondria.

Nucleolus (plural: nucleoli): A densely staining basophilic body present in the nucleus (one or more) of all plant and animal cells during interphase and early prophase, composed principally of RNA.

Obesity: Overweight of the body due to excessive accumulation of fat.

Oedema: Dropsy or abnormal infiltration of tissues with fluid.

Orgasm: A state of highly emotional excitement that occurs at the climax of sexual intercourse.

Orthologous species: Refers to corresponding members of a species.

Osmosis: The process that involves the movement of water through a semipermeable membrane from a solution of low concentration of salts to one of high concentration.

Oxidation: A chemical reaction involving the loss of one or more electrons or hydrogen atoms as also the gain of oxygen atoms by the oxidised substance, or a reaction in which oxygen combines with a substance with the liberation of energy (heat).

Oxygen debt: The amount of oxygen required to oxidise the excess lactic acid accumulated in muscles during heavy exercise.

Pacemaker: The sinoatrial (SA) node that initiates the heartbeat and regulates the rate of contraction of the heart.

Palaeontology: The study of the past remains of plants and animals (fossils); also spelt as paleontology.

Paralogous species: Relationship between two different members of a species.

Parasite: An organism that lives in (endo) or on (ecto) another organism at whose expense it gains nourishment and, often, protection.

Partial pressure: The sum total of all the pressures exerted by all the molecules of a gas (e.g., Partial pressure of oxygen (po2) it is the sum of all the pressures exerted by all the molecules of oxygen).

Pathogen: Any organism capable of causing disease.

Peristalsis: Powerful, rhythmic waves of muscular contraction and relaxation in the walls of hollow, tubular organs (e.g., parts of digestive tract, uterus); serves to move the contents through the tube.

Phagocytosis: The engulfing of micro-organisms, other cells and foreign particles by a cell such as a white blood cell.

Phospholipid: A kind of lipid molecule (phosphatide) with phosphoric acid as its component which are structural components of all cellular membranes.

Phylogenetic system: A system of classification based on evolutionary relationships among different plants and animals.

Phylogeny: The evolutionary history of plants and animals indicating relationships of a species with others.

Placenta: The structure by which the foetus (embryo) attaches to the uterus of the mother and through which exchange of diffusible materials between the mother and foetus takes place (in animals); the tissues within the ovary to which ovules are attached (in plants).

Plaque: A layer of dense proteins on the inside of a plasma membrane. (**Atherosclerotic plaque** is a lesion resulting from accumulated cholesterol in an artery, causing obstruction).

Pleura: The membrane that covers the lungs and lines the walls of the chest and diaphragm.

Polycythemia: Disorder characterised by an above-normal hematocrit (>55%).

Polyuria: An excessive production of urine.

Portal systems: A group of veins that drain one region and lead to a capillary bed in another organ rather than directly to the heart.

Prostaglandins: A group of compounds secreted by numerous tissues with many hormone-like effects.

Pseudopodia: Temporary outgrowth of the protoplasm or any cell, usually functioning in locomotion.

Puberty: The period of life when the gonads become functional, i.e., an individual becomes sexually mature.

Purines: Nitrogenous bases found in the nucleic acids RNA and DNA. Adenine and guanine are *the only purine components of both types of nucleic acids.* Purines differ from *pyrimidines* in being double-ring compounds.

Pyrimidines: Nitrogenous bases found as components of nucleic acids RNA and DNA. There are three types of pyrimidines in nucleic acids of which only two types occur in a particular nucleic acid—*cytosine* and *thymine* in DNA and *cytosine* and uracil in RNA. They differ from purines in being single-ring compounds in contrast to the double-ring structure of purines.

Radiocarbon dating: The method of finding out the age of fossils by determining the amount of radiocarbon (^{14}C) remaining in them. Since the half-life of ^{14}C is 5720 years, its amount is reduced to half after so many years and, thus, the age of a fossil can be determined.

Receptor: A specialised cell or a distal portion of a neuron that perceives to a specific sensory stimuli.

Recessive gene: A gene that cannot express itself in the presence of another allelic gene (dominant gene).

Ribonucleic acid (RNA): A type of nucleic acid present in all living cells and concerned with protein synthesis. It consists of a single helix (in contrast with DNA) and is made up of ribonucleoides which in turn are composed of ribose (a 5-carbon sugar; and hence the name), a phosphoric acid molecule, and a nitrogenous base (of 4 types, as in DNA, but thymine of DNA is replaced by uracil in RNA). There are three types of RNAs—messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA).

Ribosomal RNA (rRNA): Ribonucleic acid which is a component of ribosomes, the cell organelles which function as the *site for protein synthesis*.

Rickettsia: Small parasitic micro-organisms that are smaller in size than bacteria and larger than the viruses; have their natural habitat in the cells of the guts of arthropods.

Savannah: A grassland with scattered trees.

Secretion: Substance or fluid produced and released by cells.

Senescence: The process of growing old; the period of old age.

Serum: Blood plasma without clotting proteins.

Sphygmomanometer: An instrument for measuring arterial blood pressure.

Spore: A unicellular or multicellular, asexual reproductive body produced by a haploid or diploid generation.

Stem cell: A mitotically active somatic cell from which other cells arise by differentiation.

Symbiosis: An association between two or more species of organisms to their mutual benefit.

Synapse: The functional junction between two neurons or between a neuron and an effector viz. a muscle or a gland.

Syngamy: The fusion of a male gamete with an egg (same as fertilisation).

Systole: The phase of contraction of the heart muscle (particularly the ventricles), in the cardiac cycles.

Terrestrial: Those organisms that spend most or all their lives on land.

Thrombin: The enzyme derived from prothrombin which converts fibrinogen to fibrin; participates in blood clotting.

Thrombosis: The formation of a clot in an unbroken blood vessel.

Thromboplastin: An enzyme which converts prothrombin (inactive enzyme) into thrombin (active enzyme).

Tissues: Groups of cells with similar structure and function

Toxoid: A toxin treated to decrease its toxicity but will still allow it to cause antibody production.

Trisomy: A condition in which a particular chromosome is present in the body cells in triplicate rather than in duplicate, e.g., in the body cells of certain individuals suffering from *Down's Syndrome,* the chromosome 21 is found in triplicate. Such individuals therefore, have 47 chromosomes in their body cells rather than 46 as found in normal human beings.

Valve: Thin folds forming flap like cusps in the veins and between atrium and ventricles of the heart, allowing unidirectional flow of blood.

Vector: An organism that transmits pathogens or parasites.

Vein: A blood vessel that conveys blood from tissues back to the heart.

Vestigial (or rudimentary organs): Useless remnants of a structure or organ which was once functional in the ancestors.

Villi: Short fingerlike extensions on many membrane surfaces such as those found in the small intestine.

Zygote: The fusion product of an egg and a male gamete (sperm), i.e., a fertilised egg or ovum.

MULTIPLE CHOICE QUESTIONS

1. What should be the concentration of saline in intravenous solutions administered to patients?
   (a) 0.7%
   (b) 0.5%
   (c) 0.9%
   (d) 0.1%
2. The sport drink that players consume to “rehydrate” after a workout is:
   (a) Hypotonic
   (b) Hypertonic
   (c) Isotonic
   (d) None
3. “Digitalis” is often given to patients with weakened pumping action of the heart, because :
   (i) It strengthens the heart beat.
   (ii) It slows the sodium-potassium pumps.
   (iii) Increases the level of Ca2+ in the cytosol.

Which of the above statement/s is/are true?
   (a) (i) only
   (b) (ii), (iii)
   (c) All the above
   (d) (i), (iii)

4. HIV which causes AIDS, enters the ‘T’ helper cells, via:
   (i) A receptor protein called CD4.
   (ii) Through endocytosis.
   (iii) By symporters.
   (iv) By antiporters.
   (a) Only (i)
   (b) Only (ii)
   (c) (i) & (ii)
   (d) (ii) & (iii)
5. The example of a *flagellum* in the human body is
   (a) Respiratory lining

(b) Sperm’s tail
(c) Fallopian tubes
(d) Microvilli of small intestine

6. Which of the following statements about Tay-sachs disease is/are true?
   (i) It is a genetic disorder.
   (ii) It affects the adults above the age of 25.
   (iii) It is caused by absence of single lysosomal enzyme.
   (iv) It is caused by single autosomal recessive gene.
   (a) (i), (iii), (iv)
   (b) (ii) & (iii)
   (c) Only (iv)
   (d) (i), (ii), (iv)
7. What is “Apoptosis”?
   (i) It is similar to “necrosis”.
   (ii) It refers to cell death from tissue injury.
   (iii) It refers to cell death due to ageing.
   (iv) It is programmed cell death.

Which of the above statement/s is/are true?

(a) (i) & (ii)
(b) (i) & (iii)
(c) Only (i)
(d) Only (iv)

8. The tissue type that can detect changes in the external and internal environments is:
   (a) Nervous tissue
   (b) Muscle tissue
   (c) Connective tissue
   (d) Epithelial tissue
9. A U-shaped bone, that doesn’t articulate with any other bone is:
   (a) Ribs
   (b) Maxilla
   (c) Fibula
   (d) Hyoid bone
10. How many normal curvatures does the human vertebral column contain?
   (a) 1
   (b) 2
   (c) 3
   (d) 4

11. If a mattress keeps your spine perfectly straight, just like when you were born. Would you buy such a mattress?

(a) Yes, because it keeps the spine straight.
(b) Yes, because a straight spine provides a great sleep.
(c) No, because the spine should be curved, when we sleep.
(d) No, because an adult vertebral column shows normal curvatures.

12. The head is held upright, when a person is awake, because:

(i) Postural muscles contract continuously when a person is awake.
(ii) Skeletal muscle contractions stabilise joints.
(iii) Functioning of bones, joints and skeletal muscles is integrated.
(iv) Sustained contractions occur in the neck muscles.

Which of the above statements is/are true?

(a) Only (i)
(b) (i) & (ii)
(c) (ii) & (iii)
(d) (ii) & (iv)

13. The "gray matter" of spinal cord refers to:

(i) The part of spinal cord containing myelinated axons.
(ii) White matter from an old person.
(iii) It looks grayish because of presence of Nissl bodies.
(iv) It contains cell bodies, dendrites and neuroglia.

Which of the above statements is/are true?

(a) (i) & (iii)
(b) (i) & (ii)
(c) (ii) & (iii)
(d) (iii) & (iv)

14. In the central nervous system, little or no repair of damage to neurons can occur, because of:

(i) Inhibitory influences from neuroglia, particularly oligodendrocytes
(ii) Absence of neurolemma
(iii) Absence of growth-stimulating signals
(iv) Absence of intact cell-body

Which of the above statements is/are true?

(a) (i) & (ii)
(b) (ii) & (iii)
(c) (iii) & (iv)
(d) All the above

15. The hippocampus of brain functions in:

(a) Memory
(b) Coordinates movements
(c) Regulation of heart rate, respiratory rate, swallowing, coughing, etc.
(d) Emotions & behaviour

16. You cannot "hear" with your eyes, because:

(a) Hearing is a special sense & vision is general.
(b) Sensory neurons for sight carry information only for vision.
(c) Hearing receptors are selective and vision receptors are not.
(d) Hearing receptors produce a generator potential & vision receptors produce a receptor potential.

17. The structures associated with maintaining dynamic equilibrium are:

(a) Muscles
(b) Internal ear
(c) Nervous system
(d) Bones

18. Steroid hormones are effective when taken by mouth, because:

(i) Their peptide bonds are broken, when taken as injection.
(ii) Digestive enzymes destroy them.
(iii) They are not split apart during digestion.
(iv) They easily cross the intestinal lining because they are lipid soluble.

Which of the above statements is/are true?

(a) Only (i)
(b) (ii) & (iii)
(c) Only (iv)
(d) (i) & (ii)

19. The hormone which utilises *positive feedback mechanism* to regulate its secretion, is:

(a) Thyroid stimulating hormone
(b) Follicle stimulating hormone
(c) Prolactin
(d) Oxytocin

20. The protein hormone secreted by the ovaries is:

(i) Estrogen
(ii) Progesterone
(iii) Relaxin
(iv) Inhibin

Select the correct answer from those given below.

(a) Only (i)
(b) (i) & (ii)
(c) Only (iii)
(d) (iii) & (iv)

21. Which of the following hormones initiates the “fight or flight” response?
(a) Epinephrine or nor-epinephrine
(b) GH
(c) TSH
(d) Cortisol

22. The gland which forms a major link between the nervous and endocrine systems and acts as an endocrine gland itself, is:
(a) Pineal gland
(b) Hypothalamus
(c) Pituitary gland
(d) Brain

23. The class of adrenal gland hormones that provides resistance to stress, is:
(a) Glucocorticoids
(b) Mineralocorticoids
(c) Catecholamines
(d) Sympathomimetics (mimic sympathetic nervous system)

24. Which of the following endocrine glands, is a compound gland, (i.e., both an exocrine and an endocrine gland)?
(a) Pituitary
(b) Adrenal gland
(c) Pancreas
(d) Hypothalamus

25. Which of the following endocrine glands has two different embryological origin?
(i) Pituitary gland
(ii) Hypothalamus
(iii) Adrenal gland
(iv) Pancreas

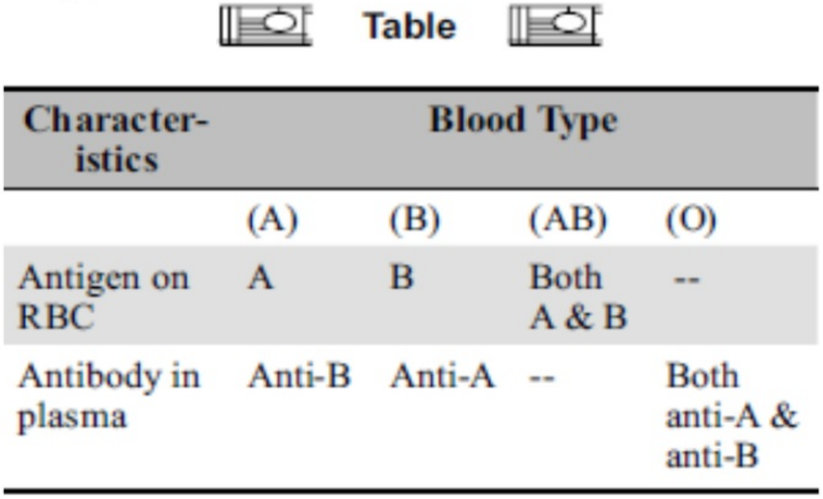
Select the correct option from those given below:
(a) (ii) & (iii)
(b) (i) & (ii)
(c) Only (iv)
(d) (i) & (iii)

26. Every sleeping room should have a smoke detector, because:

(a) Smoke detector stimulates auditory input.
(b) Smoke contains carbon-monoxide which is lethal.
(c) Smoke detector stimulates the RAS (Reticular Activating System) to awaken.

27. During REM (Rapid Eye Movement) phase of deep sleep:
(i) Dreaming occurs.
(ii) Paralysis of most muscles occur.
(iii) Most reflexes are intact.
(iv) Muscle tone is decreased slightly.

Which of the above statement/s is/ are true?
(a) (i), (ii)
(b) (iii) & (iv)
(c) (ii) & (iv)
(d) All the above



Table

Character-istics	Blood Type			
	(A)	(B)	(AB)	(O)
Antigen on RBC	A	B	Both A & B	--
Antibody in plasma	Anti-B	Anti-A	--	Both anti-A & anti-B

28. Based on the above information, which blood group can serve as “universal donor”?
(a) ‘A’
(b) ‘B’
(c) ‘AB’
(d) ‘O’

29. Which of the following statements explain why RBCs are highly specialised for oxygen transport?
(i) RBCs contain haemoglobin.
(ii) RBCs lack a nucleus.
(iii) The biconcave shape provides large surface area for the diffusion of gases.
(iv) RBCs can carry four oxygen molecules per hemoglobin molecule.
(a) (i), (iii) & (iv)
(b) (i), (ii) & (iii)

(c) (ii), (iii) & (iv)
(d) (i), (ii) & (iv)

30. A person with type ARh- blood needs transfusion. Which out of the following donors can donate blood to such a patient?

(i) ARh+
(ii) BRh–
(iii) ORh–
(iv) ARh–
(a) Only (i)
(b) (iii) & (iv)
(c) (ii) & (iii)
(d) Only (iii)

31. The human heart continues to beat even after it's removed from the body although all its nerves have been cut, because:

(i) Origin of heart beat is *myogenic* in nature (originates in muscle).
(ii) The heart contains autorhythmic fibres.
(iii) The electrical activity begins at sinu-atrial node.
(iv) The rhythmic electrical activity causes contraction of the heart.

Choose the correct option from those given below.

(a) Only (i)
(b) (ii)
(c) (i) & (ii)
(d) (ii) & (iii)

32. A student recording his/her own ECG in a physiology lab, records an ectopic (displaced) beat, because:

(i) He/she has consumed 5 cups of coffee.
(ii) He/she has taken nicotine.
(iii) He/she has done exercise.
(iv) He/she has been fitted with an artificial "pacemaker".

Which of the following options are true?

(a) Only (i)
(b) Only (ii)
(c) (i), (ii) & (iii)
(d) (iii) & (iv)

33. The phonocardiogram records a sound, which is louder and lasts a bit longer, associated with blood turbulence. It's:

(i) First heart sound

(ii) Second heart sound
(iii) "lubb"
(iv) "dupp"
(a) Only (i)
(b) (i) & (iii)
(c) (i) & (ii)
(d) (ii) & (iii)

34. Which of the following is the correct route of blood through the heart?

(a) Right atrium - tricuspid valve - Right ventricle - pulmonary semilunar valve - Left atrium - mitral valve - Left ventricle - aortic semilunar valve

(b) Left atrium - tricuspid valve - Left ventricle - pulmonary semilunar valve - Right atrium - mitral valve - Right ventricle - aorta

(c) Left atrium - pulmonary semilunar valve - Right atrium - tricuspid valve - Left ventricle - aorta - Right ventricle - mitral valve

(d) Right atrium - mitral valve - Right ventricle - pulmonary semilunar valve - Left atrium - tricuspid valve - Left ventricle - aortic semilunar valve.

35. The wall of the left ventricle is *double* in thickness to that of right ventricular wall, because:

(a) Left ventricle is a larger chamber of the heart.
(b) Left ventricle receives the blood from left atrium.
(c) Left ventricle has to push the blood through pulmonary arteries.
(d) Left ventricle supplies blood to the branches of greater or systemic circulation.

36. When you stand, the pressure pushing blood **up** the veins in your lower limbs is opposed by the force of gravity, which pushes down. The mechanism which can "pump" the blood from the lower body back to the heart can be:

(i) The contraction of the heart — "heart pump".
(ii) The contraction of the leg muscles — "skeletal pump".
(iii) The contraction of diaphragm due to respiration — "the respiratory pump".
(iv) The contraction of veins — "vasoconstriction".

Choose the correct option/s from those given below.

(a) Only (i)
(b) (i), (iv)
(c) (ii), (iii)
(d) (i), (ii) & (iii)

37. Penicillin and some drugs are responsible for some allergic reactions, because:

(i) Penicillin combines with proteins to form immunogenic complexes.
(ii) Penicillin is a "hapten" (a substance that has reactivity but no immunogenicity).

(iii) Penicillin is an antigen, which evokes antibody formation.

Which of the above statement/s is/are true?

(a) Only (i)
(b) Only (ii)
(c) Only (iii)
(d) (i) & (ii)

38. Plastic materials can be used in artificial heart valves or joints, because:

(a) They have large molecular weights.
(b) They have repeating, simple units.
(c) They are made of proteins.
(d) They are not usually antigenic.

39. Anita was suffering with flu so, her mother took her to the doctor for medicine and at the same time, the mother took a vaccination against flu. Anita was puzzled! Why did her mother take the vaccine even when she was not sick? While explaining Anita, that the vaccine will protect her (mother) from future attack of flu, write the correct sequence of events.

(i) Vaccination introduces a weakened or killed virus in the body.

(ii) This will produce a secondary response, which will prevent a case of flu.

(iii) Upon exposure to the same flu virus (present in the vaccine), body produces antibodies.

(iv) The immune system recognises the antigen.

(a) (i), (ii), (iii), (iv)
(b) (i), (iv), (iii), (ii)
(c) (i), (iii), (ii), (iv)
(d) (i), (iv), (ii), (iii)

40. One day Seema decided to clean her room. But sometime after cleaning, she started sneezing, sniffing, gasping and she developed running eyes, inflammation of skin, redness, etc. These symptoms indicate that:

(a) She has been attacked by influenza virus while cleaning.
(b) She is not used to cleaning the room.
(c) She is allergic to dust.
(d) She was not vaccinated.

41. Meera went to a *Rhinoplast* for cosmetic surgery. In your opinion which part of her face needs correction by the doctor?

(a) Face
(b) Chin
(c) Ear lobes

(d) Nose

42. The cartilage is absent between the trachea and the esophagus. The possible reason for this can be:
(a) The cartilage is present only in the trachea.
(b) The neck tissues are soft.
(c) The neck muscles support the back of the trachea.
(d) To allow esophagus to bulge and press against the trachea during swallowing.

43. If the amount of blood pumped by the heart in each heart beat is 70ml and total number of heart beats is 72 beats/minute; then, in your opinion, the **total amount of blood**pumped by the heart each minute should be:
(a) 70 ¥ 72
(b) 70 ∏ 72
(c) 70 + 72
(d) 72 – 70

44. For inhalation to occur, air pressure in the alveoli must be _______ than the atmospheric pressure. Fill in the blank with the correct option from those given below.
(a) Less
(b) More
(c) Equal
(d) Can not be said

45. If you keep bread in the mouth for a long time, it starts tasting “sweet”, because:
(i) Bread is made up of monosaccharide and disaccharide sugars.
(ii) The chemoreceptor in the taste buds becomes stimulated by chewing the bread.
(iii) The enzyme salivary amylase acts on starch (bread) to convert it into a mixture of dextrins and sugar in the mouth.
(iv) Saliva softens the bread, making it sweet.

Which of the above statements is/are true?
(a) Only (i)
(b) Only (iii)
(c) (ii) & (iii)
(d) (i) & (iv)

46. The enzymes viz. pepsin are secreted in their inactive form because:
(a) The enzyme is activated only when it’s needed.
(b) It prevents “self-digestion” or autolysis of cells/tissues.
(c) An enzyme is a protein in nature.
(d) An enzyme needs an activator.

The following questions (Q.No. 47–53) include two statements, one (1) and two (2). Examine these statements carefully and select your answer from the codes given below:

(a) Both are true
(b) Neither 1 nor 2
(c) Only 1
(d) Only 2

47. 1. It is impossible for people to kill themselves by holding their breath.
2. Respiratory rhythm is involuntary.

48. 1. Pernicious anaemia is due to malformation of RBCs and the person feels fatigued, skin is pale and is intolerant of cold.
2. It's caused due to deficiency of vitamin B_{12} resulting in the inability of the stomach to produce intrinsic factor.

49. 1. Sickle-cell anaemia is a genetic disorder, resulting in the increase in the number of RBCs.
2. It's caused due to toxins, which stimulate hemopoiesis.

50. 1. Biosphere reserves protect areas of natural habitat and are smaller than National Parks or Animal Sanctuaries.
2. Protection is granted only to the flora and fauna and not to the human communities inhabiting these regions.

51. 1. The testes in human beings are located in the scrotal sacs, inside the abdominal cavity.
2. It helps in mating or copulation.

52. 1. Pouched mammals (marsupials) viz. Kangaroo are now mostly confined to S. America.
2. The continent of Australia separated from Pangaea before the origin of placental mammals.

53. 1. *Australopithecus* is considered to be first "bi-pedal" ancestor of modern man.
2. The foramen magnum (hole through which the spinal cord passes through the skull to connect to the brain) faces downward and the pelvis is broad and flat in their fossils.

54. Stomach may also be termed as "endocrine", because:
(a) It secretes pepsin, HCl and mucus.
(b) It releases its secretion in the blood stream.
(c) Gastric secretions are regulated by negative feedback mechanism.
(d) G-cells of the stomach secrete a hormone, known as Gastrin.

55. The following table shows the substances filtered, reabsorbed and excreted in urine. After studying the table, answer the following question.

Substance	**Filtered**	**Reabsorbed**	**Urine**

Water	180L	178–179L	1–21
Proteins	2.0g	1.9g	0.1g
Glucose	162g	162g	0g
Urea	54g	24g	30g
Creatinine	1.6g	0g	1.7g

(i) Glucose is completely reabsorbed.
(ii) Urea is partially reabsorbed.
(iii) Proteins are secreted into urine.
(iv) Creatinine is secreted into urine.

Which of the above statements is/are true?

(a) (i), (ii), (iii)
(b) (i), (iii)
(c) (i), (ii), (iv)
(d) (ii), (iii), (iv)

56. If the urinary excretion rate of a drug viz. penicillin is greater than the rate at which it is filtered at the glomerulus; how do you think it is gets into the urine?

(a) By excretion
(b) By filtration
(c) By reabsorption
(d) By secretion

57. The hormone secreted by the kidneys is:

(a) ADH
(b) Calcitriol
(c) Erythropoietin
(d) Aldosterone

58. Out of the following, which features, in your opinion, would increase the filtering capacity of renal corpuscle?

(i) Large glomerular capillary surface area
(ii) Low glomerular capillary pressure
(iii) Thin and porous filtration membrane
(iv) High glomerular capillary pressure

Choose the correct option/s from those given below.

(a) (i), (ii), (iii)
(b) (i), (iii), (iv)
(c) (i), (ii)

(d) (ii), (iii), (iv)

59. The primary oocyte of the female gets *arrested* in one of the following phases of meiosis, till puberty. Which of the following options is true about this statement?

(a) Prophase I
(b) Metaphase I
(c) Anaphase I
(d) Telophase I

60. The secondary oocyte begins meiosis II, but gets *arrested* in one of the following stages of meiosis. Which of the following options is true about this statement?

(a) Prophase II
(b) Metaphase II
(c) Anaphase II
(d) Telophase II

61. The secondary oocyte begins meiosis II, but gets arrested in the metaphase stage. When does it get completed ?

(a) At puberty
(b) At menopause
(c) At menstrual cycle
(d) At fertilisation (fusion with sperm)

62. The human testes descend in the scrotal sacs, because:

(i) Scrotal sacs have a lower temperature than pelvic cavity.
(ii) Pelvic cavity promotes the division of germ cells.
(iii) Spermatogenesis doesn't occur at normal core body temperature.
(iv) Pelvic cavity can't accommodate testes.

Choose the correct option/s from those given below.

(a) (i), (iii)
(b) (ii), (iii)
(c) (i), (ii)
(d) (ii), (iv)

63. The concept of organic evolution—that life evolved slowly from simple to more complex forms, was developed on the basis of the study of *fossils*. This branch of science is known as:

(a) Paleozoology
(b) Palynology
(c) Geology
(d) Palaentology

64. Which of the following fossils discovered from the limestone rocks 150mya showed

that birds (Aves) arose from reptiles?
(a) *Ornithorhyncus*
(b) *Archeopteryx*
(c) *Pterosaurs* (Flying reptiles)
(d) *Dinosaurs*

65. Match the following:
A. Ornithology (1) Study of reptiles & amphibians
B. Herpetology (2) Study of insects
C. Helminthology (3) Study of birds
D. Entomology (4) Study of parasitic worms
E. Ichthyology (5) Study of fishes

The correct order is:
A B C D E
(a) 1 2 3 4 5
(b) 2 3 1 5 4
(c) 3 1 4 2 5
(d) 5 3 2 4 1

66. The Indian Government is encouraging the breeding of honey-bees and technique of obtaining honey from them. This culturing technique is known as:
(a) Sericulture
(b) Apiculture
(c) Silviculture
(d) Viticulture

67. Match the following:
A. White Revolution (1) Increase in crop production
B. Green Revolution (2) Increase in fish production
C. Blue Revolution (3) Increase in milk production
D. Silver Revolution (4) Increase in egg production

The correct order is:
A B C D
(a) 1 2 3 4
(b) 2 1 4 3
(c) 4 3 2 1
(d) 3 1 2 4

68. These cell organelles are bags of hydrolysing enzymes, digesting the whole cell or part of it, often known as “suicide bags”. Which organelle are we referring to?
(a) Peroxisomes

(b) Centrosome
(c) Ribosomes
(d) Lysosomes

69. Ribosomes are cell organelle, present both in prokaryotes and eukaryotes, made of two sub-units. Which of the following functions is performed by them?

(a) These are “powerhouses of the cell”, concerned with aerobic metabolism.
(b) These are sites of protein synthesis.
(c) They secrete oxidative enzymes.
(d) They are concerned with the organisation of mitotic spindle.

70. “Kuru” is:

(a) A tribal art form practiced by ancient man.
(b) Narcotic product related to “charas”.
(c) An infectious disease, associated with brain cells, caused by a *prion*.
(d) A by-product of turmeric.

71. Each phylum of animals is characterised with its unique features. Some animal phylum and their unique feature pairs are given below:

(i) Porifera—Animals can exist in two body forms—polyp and medusa.
(ii) Mollusca—Soft, unsegmented animals with a fold of skin—the “mantle”.
(iii) Coelenterata—Bear numerous pores (“ostia”) on the body.
(iv) Arthropoda—Jointed limbs present.

Which of the above is/are matched correctly?

(a) (ii) and (iv) only
(b) (i) and (iii) only
(c) (ii) and (iii) only
(d) (i) and (iv) only

72. Each phylum of animals is characterised with its unique features. Some animal phylum and their unique feature pairs are given below:

(i) Amphibia—Cold-blooded vertebrates which can live both on land and in water.
(ii) Aves—Warm-blooded vertebrates with milk glands for nourishment of young.
(iii) Reptilia—Warm-blooded with feathers and wings for aerial mode of life.
(iv) Mammalia—Cold-blooded vertebrates with a hard, scaly skin.

Which of the above is/are matched correctly?

(a) (i) and (ii)
(b) Only (i)
(c) (i) and (iii)
(d) (i) and (iv)

73. Which of the following groups of animals show the following characters?

(i) Spiny-skinned
(ii) Bear a water-vascular system of tube-feet for locomotion
(iii) Live *only* in sea water
(iv) Built on five or penta-radial plan
(a) Porifera
(b) Arachnida
(c) Echinodermata
(d) Urochordata

74. Which of the following statements/about *white blood cells*, make them effective *defence* agents?
(i) They are amoeboid in nature.
(ii) They are large and colourless.
(iii) They possess specific type of nuclei viz. bean-shaped, etc.
(iv) They are phagocytotic in nature.
(a) (i), (iv)
(b) (i), (ii)
(c) (i), (iii)
(d) (ii), (iii)

75. Which of the following statement/s about *cardiac muscle fibres is/*are true?
(i) They are uni-nucleate.
(ii) They are long, highly branched muscle fibres.
(iii) They bear inter-calated discs.
(iv) They are voluntary in nature.
(a) (i), (iv)
(b) (i), (ii)
(c) (ii), (iii)
(d) (iii), (iv)

76. Each animal bears an unique characteristic structure, which helps in its identification. Some structure and animal pairs are given below:
(i) Ink gland—Sea-horse
(ii) Hood with spectacle mark—Octopus
(iii) Pre-hensile tail—Cobra
(iv) Lungs—Whale

Which of the above is/are matched correctly?
(a) All the above
(b) None of the above
(c) Only (i)

(d) Only (iv)

77. A *labourer* sleeps for 8 hours (*576* kcal), works very hard for 8 hours in the sun, works for another 2 hours. Depending on his energy requirements, what should be the correct proportion of various food substances in his diet?
    (a) Carbohydrates > Proteins > Vitamins & Minerals
    (b) Carbohydrates > Vitamins & Minerals > Proteins
    (c) Proteins > Carbohydrates > Vitamins & Minerals
    (d) Proteins > Vitamins & Minerals > Carbohydrates

78. The total number of bones in an average adult human skeleton is
    (a) 106
    (b) 206
    (c) 306
    (d) 406

79. What is the correct sequence of chromosome numbers in **honey bees**—queen, males and workers respectively?
    (a) 32, 16, 16
    (b) 16, 32, 32
    (c) 16, 32, 16
    (d) 32, 16, 32

80. *Identical twins* develop from a *single* fertilised ovum, which separate into two embryos. If separation occurs later than 8 days, it's likely to produce:
    (a) Monozygotic twins
    (b) Dizygotic twins
    (c) Conjoined twins
    (d) The embryo aborts.

81. How is it possible for a baby to have type O blood if neither parent is type O?
    (a) AO X BO (IA i X IB i)
    (b) AB X BO (IA B X IB i)
    (c) AO X AB (IA I X IA IB)

82. If the SRY gene is present and functional in a fertilised ovum, the foetus will differentiate into a:
    (a) Female
    (b) Male
    (c) Hermaphrodite
    (d) None of the above

83. In DNA double helix, which one of the following shows the correct sequence of nitrogenous bases:

(a) A @T, G @C
(b) A = T, G @C
(c) A @T, G = C
(d) A = G, C @T

84. Most amino-acids are coded by more than one codon of nucleotides. This property of the genetic code is known as:
(a) Triplet code hypothesis
(b) Co-linearity of code
(c) Universal code
(d) Degenerate code

85. If the sequence of nitrogenous bases in one of the DNA strands is AGCTGA, then the sequence in the complementary strand should be:
(a) TCGACT
(b) UCGACT
(c) GTGATG
(d) TAGAAT

86. Each disease is caused by a causative agent. Some disease-causative agent pairs are given below:
(i) Common cold—Variola virus
(ii) Tetanus—*Yersinia pestis*
(iii) Small pox—*Clostridium tetani*
(iv) Bubonic plague—Rhinovirus

Which of the above pair/s is/are matched correctly?
(a) All the above
(b) None of the above
(c) (i), (iii) and (iv) only
(d) (ii) and (iv) only

87. Each disease is caused by a causative agent. Some disease—causative agent pairs are given below:
(i) AIDS—HTLV-III (HIV)
(ii) Malaria—*Plasmodium*
(iii) Sleeping sickness—*Leishmania donovani*
(iv) Kala-azar—*Trypanosoma*

Which of the above pair/s is/are matched correctly?
(a) (i) and (iii) only
(b) (i) and (ii) only
(c) (i), (iii) and (iv) only

(d) (ii) and (iv) only

88. A disease is sometimes spread by a vector. Some diseases and their vector pairs are given below:

(i) Malaria—Tsetse fly
(ii) Sleeping sickness—Sand fly
(iii) Kala-azar—*Aedes* mosquito
(iv) Dengue fever—Female *Anopheles* mosquito

Which of the above pair/s is/are matched correctly?

(a) None of the above
(b) All the above
(c) (i), (ii) and (iv) only
(d) (ii), (iii) and (iv) only

89. Vitamins are essential for the body. Their deficiency results in a number of diseases. Some vitamins—deficiency disease pairs are given below:

(i) Vitamin C—Night Blindness
(ii) Vitamin B_1—Beri-beri
(iii) Vitamin D—Rickets
(iv) Vitamin A—Scurvy

Which of the above pair/s is/are matched correctly?

(a) (i) and (iv) only
(b) (ii) only
(c) (ii) and (iii) only
(d) (ii) and (iv) only

90. Lamarck, a French biologist, believed that "desired" characters can be acquired and inherited. But his view was later rejected, because:

(i) Characters are present because of inner perfecting principle.
(ii) Characters present only in germ cells can be passed on to the next generation.
(iii) Characters can be acquired on the basis of use and disuse only.
(iv) One can't acquire characters simply by desiring for them.

Which of the above statement/s is/are true?

(a) (i), (ii)
(b) (ii), (iii)
(c) (iii), (iv)
(d) (ii), (iv)

91. Analysis of Mighi meteorite in Ukraine by space biologists revealed that polynucleotide DNA found there is of *chemical* origin and not biological origin; because :

(i) DNA strands contained adenine and thymine and cytosine and guanine.
(ii) DNA strands showed same chemical composition.
(iii) DNA strands were identical in nature.
(iv) DNA strands were complementary in nature.

Which of the above statement/s is/are true?

(a) Only (i)
(b) (ii), (iv)
(c) Only (iii)
(d) (ii), (iii)

92. Which of the following low molecular weight polysaccharides is used to measure Glomerular Filtration Rate (GFR)?

(a) Mannose
(b) Glucose
(c) Inulin
(d) Insulin

93. National Parks have characteristic animal fauna. Some National parks and their fauna pairs are given below:

(i) Periyar, Kerela—White Tiger, Asiatic Lion
(ii) Gir, Gujarat—Royal Bengal Tiger
(iii) Sunderbans, West Bengal—Tiger, Lion-tailed Macaque
(iv) Nandan Kanan, Orissa—Asiatic Lion, Leopard

Which of the above pair/s is/are matched correctly?

(a) None of the above
(b) All the above
(c) (ii) and (iii) only
(d) (i) and (iv) only

94. Green Revolution, Yellow Revolution and White Revolution are all examples of:

(a) Natural selection
(b) Sexual selection
(c) Artificial selection
(d) Group selection

95. *Archeopteryx*, a fossil discovered from upper Jurassic in Bavaria (in 1861) is proposed to be a “missing link”, because:

(a) It was found to be missing from sedimentary rocks.
(b) The paleontologists’ “missed” the study of this link between organisms.
(c) Some parts of the fossil were missing. It wasn’t complete.
(d) It represented an intermediate form between reptiles and birds.

96. A fisherman was fishing in the deep waters off the eastern coast of South Africa. He accidentally came across a live, ancient lobe- finned fish, related to terrestrial vertebrates about 200 million years ago. These findings show the presence of:

(a) Extinct fossils
(b) Missing fossils
(c) Living fossils
(d) Relict fossils

97. Is there life elsewhere in the universe? This question has baffled scientists for long. Planet Mars seems to be a strong contender, because:

(a) The volcanoes are found on its surface.
(b) The atmosphere is reducing.
(c) Silicon and ammonia have been found there.
(d) Salt pools are present there.

98. The Himalayan Mountains attained their present towering heights, due to:

(i) The collision of Indian plate with the Asian Plate.
(ii) Geological events viz. folding.
(iii) Compressional forces exerted by colliding landmasses.
(iv) Movement of continental plates with respect to each other.

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Choose the correct option/s from those given below.

(a) (i), (ii)
(b) (ii), (iii)
(c) (iii), (iv)
(d) All of the above

99. The fossil remains of echinoderms werediscovered from Himalayas. This finding indicates that Himalayas:

(a) Had rich bio-diversity.
(b) They are very ancient.
(c) They were once submerged under the sea.
(d) The origin of echinoderms and formation of Himalayas occurred roughly at the same time.

100. Chimpanzee is supposed to be our closest relative. Which of the following do you think is the best evidence to prove this point?

(a) Both are morphologically similar.
(b) Both have similar anatomical features.
(c) Molecular analysis of globins pseudo gene differs only by 2%.
(d) A common ancestor of humans and chimpanzees was a large arboreal African ape.

101. A popular politician died at the ripe age of 80 years. His body was kept for public

"darshan" for 7–8 hours. Then, the body was taken for cremation. But suddenly at the crematorium, he showed some movement. It was because:

(a) He had revived.
(b) He had some mysterious powers.
(c) His muscles had become stiff, due to "rigor mortis" ("rigidity of death").

(d) A person is not "brain-dead" till 7–8 hours.

102. "Heart burn" is observed due to:
(a) A burning sensation in the heart.
(b) A burning sensation observed due to eating "hot" and spicy food.
(c) Increased acidity in the stomach which irritates the esophageal wall.
(d) Heaviness observed due to indigestion and over-eating.

103. Yawning or hiccupping is observed in a person:
(i) Because of hypoxia (low oxygen).
(ii) Because one is feeling sleepy.
(iii) It is a modified respiratory movement.

Which of the above statement/s is/are correct?
(a) Only (i)
(b) (i), (ii)
(c) (ii), (iii)
(d) (i), (iii)

104. Teddy bear, the favorite soft toy of children is actually:
(a) A giant Panda
(b) A Koala bear
(c) A baby bear
(d) Grizzly bear

105. Ajmer is considered to be a bird-lover heaven, because:
(i) It's the breeding ground for Lesser Florican.
(ii) A famous bird sanctuary is located here.
(iii) The daily sightings of endangered species of birds has increased.
(iv) Great Indian Bustard with chicks have been reported.

Which of the above statement/s is/are true?
(a) (ii), (iii)
(b) (i), (ii)
(c) (i), (ii), (iii)
(d) (i), (iii) & (iv)

106. Rakesh Sharma, a 55 years old army officer, when set out for his morning walk was

suddenly hit by a bout of dizziness and breathlessness. **His heart missed a beat**. Numerous tests were carried out and it was diagnosed that he was suffering from:

(a) Heart valve disease
(b) Atrial fibrillation
(c) Thyroid problem (hyperthyroidism)
(d) Sleep apnea

107. Pooja is working in a call centre. She works at night and sleeps during day. Which of the following hormones, in your opinion, shows malfunction in her body?

(a) Estrogen
(b) Progesterone
(c) ACTH
(d) Melatonin

108. The story of "Jungle Book" by Rudyard Kipling was set in a famous National Park, located in Madhya Pradesh, known for its wildlife attractions viz. tiger, leopard, elephant, swamp deer, sambhar, cheetals, sloth bear, etc. What is the name of this park?

(a) Corbett N.P.
(b) Keoledeo N.P.
(c) Manas N.P.
(d) Kanha N.P.

109. Majority of Indian population is suffering from *Diabetes mellitus* which has become a major cause of concern. Which of the following statement/s about this disease is/ are true?

(i) It is caused by *Apis mellifera.*
(ii) It is caused due to insufficient secretion of insulin.
(iii) It results in hypoglycemia.
(iv) The Indian population is genetically predisposed for this disease.

(a) (ii), (iv)
(b) (i), (ii)
(c) (i), (iii)
(d) (i), (iv)

110. Khushboo is 10 years old and is suffering from leukemia (cancer). The Doctor advised for bone marrow transplant to alleviate her problem. Consider the above statement and then choose the **best** option from the following.

(a) Chemotherapy is very painful.
(b) In children, bone narrow can be easily transplanted.
(c) Radiotherapy will kill normal cells as well.

(d) Bone marrow is the site for production of blood cells.

111. An 80 year old lady was lifting a corner of the mattress while making her bed, and she suffered a from a vertebral fracture. Which of the following statement/s can be the cause of her fracture?

(a) She was osteoporotic .

(b) She was aged and hence could not bear the weight of the mattress.

(c) She was old and hence she had become weak.

(d) She has entered post-menopausal age.

112. Laughing is a source of good health and well being, because:

(a) It stimulates the cerebral humor.

(b) It gives intellectual pleasure.

(c) It produces muscular exertion, increasing physical activity.

(d) Muscle activity producing "Ha" "Ha", triggers an increase in endorphins, the brain chemicals.

113. Which of the following, was the site of preservation of DNA used for producing live Dinosaurs in the movie "Jurassic Park"?

(a) Giant eggs

(b) Amber fossils

(c) Skin

(d) Hair

114. Which of the following, is the abbreviated form of Cc, a clone?

(a) Cubic centimeter

(b) Cancer cells

(c) Carbon copy

(d) Copy cat

115. Ram's grandfather expired at the age of 76. When Ram collected the "ashes" of his grandfather, after the last rites, he found that it had only bones. Which of the following options can be the true reason for this?

(a) Fire was not strong enough to destroy the bones.

(b) All the tissues were burnt in the fire.

(c) Since, Ram's grandfather was old; all the major organs were already in degenerate state.

(d) Bones contain mineral salts, which make them resistant.

116. Slimming centers treat the cases of obesity, using a hormone therapy, which induces "satiation", i.e., feeling of fullness, when given in high doses. Which can be the probable hormone used in such cases?

(a) Gastrin

(b) Leptin

(c) Ghrelin

(d) Secretin

117. Most of the reptiles are oviparous (egg-laying) and very few are viviparous. Which one of the following litters “young ones”?

(a) King cobra

(b) Krait

(c) Anaconda

(d) Russell’s viper

118. Tapping the patellar ligament normally causes reflex extension of the knee joint. Such reflexes have clinical significance, because:

(a) Reflexes are normally predictable.

(b) Reflexes are fast involuntary action.

(c) Somatic reflexes can be tested.

(d) Absence of such a reflex indicates damage of the sensory or motor neurons.

119. What should be the *correct* proportion of various food substances in a *growing* child? Choose the best option from the following:

(a) Fats > carbohydrates > proteins > vitamins & minerals

(b) Carbohydrates > fats > proteins > vitamins & minerals

(c) Proteins > carbohydrates > fats > vitamins & minerals

(d) Vitamins & minerals > proteins > carbohydrates > fats.

120. Consider the following statements:

(i) Bats are mammals.

(ii) Bats locate their prey by echolocation.

(iii) Bats normally eat fruits & insects.

(iv) Bats bear a wing-membrane—sthe “patagium”.

Which of the above statement/s is/are true?

(a) (i), (ii)

(b) (i), (ii), (iv)

(c) (ii), (iii), (iv)

(d) All the above

121. Consider the following statements about Lion- tailed macaque.

(i) It is highly endangered.

(ii) It is sheltered in Silent valley National Park.

(iii) It is arboreal.

(iv) It is facing habitat destruction.

Which of the above statement/s is/are true?

(a) (i), (ii)
(b) (i), (ii), (iii)
(c) (ii), (iii), (iv)
(d) All the above

122. Blood samples are stored in glass tubes in the laboratory. Which of the following chemicals is used to prevent clotting of the blood in these glass tubes?

(a) Anti-hemophilic factor
(b) heparin
(c) Calcium carbonate
(d) formalin

123. Which of the following statement/s about "Hangul" are not true?

(a) It is a reindeer.
(b) It is found only in Kashmir.
(c) It is extensively hunted for its fur.
(d) It is endangered.

124. Which of the following statement/s is/are **true** about "Chiru"?

(i) It is an antelope.
(ii) It is found in Tibet.
(iii) It is facing threat of extinction.
(iv) It is extensively hunted for the fleece, which is required for weaving the famous Kashmiri shahtoosh shawls.

(a) (i), (ii)
(b) (iii), (iv)
(c) (i), (iii), (iv)
(d) All the above

125. The following question includes two statements, one labeled as **Assertion 'A'** and the other as **Reason 'R'**. Examine these statements carefully and select your answer from the codes given below.

Assertion 'A': The cases of heart attack are more likely to occur in the morning.

Reason 'R': In the morning, sympathetic tone and cortisol ("stress hormone") levels are high.

(a) Both A & R are true and R is the correct explanation of A
(b) Both A & R are true and R is not correct explanation of A
(c) A is true but R is false
(d) A is false but R is true.

126. Drug addicts experience a false feeling of "euphoria" (or pleasure). This is observed due to secretion of which of the following neurotransmitters?

(a) Acetylcholine
(b) Dopamine
(c) Glycine
(d) Epinephrine

127. Consider the following statements about Dengue fever, which one of them is not trueabout it?
(a) It is caused by an arbovirus.
(b) It is transmitted by mosquito *Aedes* bite.
(c) Severe cases of hemorrhagic fever require platelet transfusion.
(d) It is an example of non-communicable disease.

128. Which of the following statement/s is/are **not true** about Malaria?
(a) It is transmitted only through the bite of female anopheline mosquito.
(b) The male mosquito does not bite, as it has weak mouth parts.
(c) The blood provides nourishment (protein) for the growth of eggs in the females.
(d) It is caused by a protozoan *Plasmodium*.

129. Consider the following statements about **SARS.**
(i) It is a life-threatening viral respiratory illness.
(ii) It spread as a pandemic in several countries around the world in 2002.
(iii) It started from Palm civets (a type of cat) in Guangdong Province in China.
(iv) The disease jumped across species from animals to humans.

Which of the above statement/s is/are true?
(a) (i), (ii)
(b) (ii), (iii)
(c) (iii), (iv)
(d) All of the above

130 The British Royal Family is suffering from a genetic disorder, caused by a recessive sex-linked gene, resulting in defective synthesis of a clotting factor.

Which of the following diseases is being referred to?
(a) Huntington’s disease
(b) Cystic fibrosis
(c) Hemophilia
(d) Turner’s Syndrome

131. A patient is suffering from Klinefilter’s syndrome, with an additional X chromosome (XXY). What will be the *sex* of such a patient?
(a) A female, as it has two ‘X’ chromosomes.
(b) An intersex, because it has both ‘X’ and ‘Y’ chromosomes.
(c) A sterile male, because it has an extra dose of ‘X’ chromosome.

(d) None of the above

132. "Mad cow" disease was recently in news. Which of the following statement/s is/are true about this disease?

(i) It is caused by a prion.

(ii) It is a disease which can spread from animals to humans.

(iii) This disease was responsible for a very high mortality rate of cattle in several European countries.

(iv) The affected cows suffer from a nervous disorder.

(a) (ii), (iii)

(b) (i), (ii)

(c) (iii), (iv)

(d) All the above

133. Monoclonal antibodies can be used with other drugs to treat cancer. Which of the following statement is the best option about this technique?

(a) They help in early detection of cancer.

(b) They damage only the tumor tissue and not the surrounding healthy tissue.

(c) They provide long term sources of pure and identical antibodies.

(d) All the above

134. Which of the following chemical/s is released during allergic reactions?

(a) Hapten

(b) Histamine

(c) Heparin

(d) Cytokines

135. Consider the following statement critically and choose the best option from the following.

"Rabies virus-G protein in tomato is known as an "edible vaccine", because:

(a) It is taken with tomato.

(b) It is a vaccine prepared from tomato.

(c) It involves introduction of selected desired genes into tomato and then using these altered plants to manufacture the encoded proteins.

(d) It is a vaccine directed against tomato.

136. The Human Genome Project pointed out that there were small number of genes in human genome (~30,000). The most appropriate reason for this was believed to be:

(a) About 50% of genome comprises of "junk DNA".

(b) Proteomes coded by human genome are very complex.

(c) There are several gaps in the genome.

(d) The draft of human genome is still incomplete.

137. How many different base-pair sequences are possible in a DNA molecule 10 base pairs long?
(a) 210
(b) 310
(c) 410
(d) 110

138. The understanding of molecular genetics has improved the lives of individuals suffering from haemophilia A, because:
(a) It helps in the isolation of genes.
(b) It helps in purification of genes.
(c) It provides an unlimited supply of authentic clotting factor from cultured cells.
(d) It is the only technique which can detect the disease.

139. DNA fingerprints have played an important role in the identification of victims of September 11 terrorist attack on New York's World Trade Centre. Which of the following statement/s is are most appropriate, for the above consideration?
(a) The bodies of the deceased were not recovered.
(b) The intense heat destroyed all the evidence.
(c) Much of the evidence was lost in the debris.
(d) DNA can be isolated even from a small sample of tissue, recovered at the scene.

140. Which of the following day is celebrated as the "World Environment Day"?
(a) 5th June
(b) 7th June
(c) 14th October
(d) Ist July

141. "Nagarjuna Sagar Srisailam", Hyderabad is famous for which of the following reasons?
(a) It's the largest dam in India.
(b) It's the abode of Satya Sri Saibaba.
(c) It's the biggest tiger reserve of India.
(d) It's the site of National Oceanography Institute.

142. Which of the following, in your opinion, can be the constituent of "I-pill"—the female contraceptive?
(a) Hormone Estrogen.
(b) Hormone Progesterone.
(c) Synthetic derivative of hormone Progesterone.
(d) Both Estrogen and Progesterone

143. The Western Black Rhino of Africa has been declared officially extinct, because:

(a) International crime groups engage in its illegal trading.
(b) It is poached for its horns.
(c) It is listed in the “Red List” of IUCN.
(d) Not even a single member of this species exists on the earth today.

144. Which of the following animals is used in the official logo of WWF?
(a) A Koala bear
(b) A Giant Panda
(c) One-horned rhino
(d) A Tasmanian cat

145. A fruit fly has eight chromosomes in its skin cells. How many chromosomes will be present in the gametes of the same fly?
(a) 4
(b) 8
(c) 16
(d) 2

146. Consider the following statement critically. “No two individuals can be alike in bisexually reproducing organisms”. Which of the following options can be the most appropriate reason for this?
(a) Bisexually reproducing organisms reproduce by meiosis.
(b) Variations are introduced through segregation and independent assortment.
(c) Recombination occurring during prophase I results in gametes having different combinations of the alleles of various genes.
(d) All the above

147. Albinism in humans is caused by a recessive allele ‘a’. From a marriage between a carrier (Aa) and an albino (aa), what proportion of the children would be expected to have albinism?
(a) Only 1
(b) 1/4
(c) 2/4
(d) 3/4

148. 270,000 people of Iceland provide a unique resource for genetic studies. Which of the following statement/s is are the correct reason for this?
(a) Iceland’s National Health Service has kept superb family medical records.
(b) The population of Iceland was subjected to two “genetic bottlenecks”, during which the population reduced drastically.
(c) Icelanders are descendants of Vikings.
(d) Iceland has a unique history and geographical location.

(b) Conventional X ray
(c) PET
(d) Sonography

155. A person drinks a six-pack of beer and has to make several trips to the bathroom. This increase in urination reflects an increase in a process occurring in the kidney. What is this process?
(a) Diffusion
(b) Osmosis
(c) Solute pumping
(d) Filtration.

156. The term used to describe the type of solution in which cells will lose water to their environment is:
(a) Isotonic
(b) Hypertonic
(c) Hypotonic
(d) Catatonic.

157. The gland type that secretes products such as milk, saliva, bile, or sweat through a duct is:
(a) An endocrine gland
(b) An exocrine gland
(c) An apocrine gland
(d) A holocrine gland

158. Bone growth during childhood and in adults is regulated and directed by:
(a) Growth hormone
(b) Thyroxine
(c) Sex hormone
(d) All of these.

159. Aerobic exercise is desirable because it results in all of the following except
(a) Increased cardiovascular system efficiency
(b) Increase in the number of mitochondria in the muscle cells
(c) Increase in the size and strength of existing muscle cells
(d) Increased neuromuscular system coordination.

160. Consider the following case of a suicide victim who was found dead and the doctor was unable to remove the drug vial clutched in his hand.

The correct reason for this strange stiffness of the muscles can be:
1. The muscles had atrophied (degeneration) due to death.
2. The muscle was deprived of neural stimulation.

(b) Neutrophil,
(c) Monocyte,
(d) Lymphocyte.

177. Blood proteins play an important part in
(a) Blood clotting
(b) Immunity
(c) Maintenance of blood volume
(d) All of the above

178. The white blood cell that releases histamine and other inflammatory chemicals is the
(a) Basophil,
(b) Neutrophil
(c) Monocyte
(d) Eosinophil

179. The blood cell that is said to be immunologically competent is the
(a) Lymphocyte,
(b) Megakaryocyte
(c) Neutrophil
(d) Basophil

180. Suppose your blood was found to be AB positive. This means that
(a) Agglutinogens A and B are present on your red blood cells
(b) There are no anti-A or anti-B agglutinins in your plasma
(c) Your blood is Rh+
(d) All of the above.

181 If you have severe infection, would you expect your WBC count to be closest to :
(a) 3000/mm3
(b) 5000/mm3
(c) 15,000/mm3
(d) 7000/mm3

182 Platelets should not be called as “cells”, because:
1. They don’t have nucleus
2. They are not bound by plasma membrane
3. They are very small cells.
4. They are fragments of large megakaryocytes

Choose the correct option (s) from those given below:
(a) 2 Only
(b) 1,2 & 3 Only

1. It is provided with a duct.
2. It is made largely of non-myelinated axons.
3. It releases the hormones "on demand" in response to nerve impulses.

Choose the correct option (s) from those given below:

(a) 2 & 3 Only
(b) 1 Only
(c) 1 & 3 Only
(d) 3 only

171. Johnny, a five year old boy has been growing by leaps and bounds; his height is 100% above normal for his age. What hormone is being secreted in excess?

(a) Insulin
(b) Testosterone
(c) Growth Hormone
(d) TSH

172. Athletes use anabolic steroids to improve their performance. Which of the following chemicals can be used as "drugs" by athletes?

(a) Adrenocorticosteroids
(b) Testosterone
(c) Estrogen
(d) Growth hormone

173. The blood volume in an adult averages approximately

(a) 1 Litres
(b) 3 Litres
(c) 5 Litres
(d) 7 Litres

174. The hormonal stimulus that prompts red blood cell formation is

(a) Serotonin
(b) Heparin
(c) Erythropoietin,
(d) Thrombopoietin.

175. All of the following are true of RBCs except

(a) Biconcave disc shape
(b) Life span of approximately 120 days
(c) Contain hemoglobin
(d) Contain nuclei

176. The most numerous WBC is the

(a) Eosinophil,

149. Stem cell therapy uses mainly embryonic cells. Which of the following statement/s is/are true about this therapy?

(i) They are capable of endless reproduction.
(ii) They can differentiate into special cell types.
(iii) They are derived mainly from embryonic stem.
(iv) Adults cannot be sacrificed while embryos are more freely available.
(a) (i), (ii)
(b) (ii), (iii)
(c) (iii), (iv)
(d) (i), (iv)

150. What steps in the cell cycle represent irreversible commitments?

(i) The S/G2 checkpoint
(ii) The G1/S checkpoint
(iii) Anaphase

Which of the following option/s is/are true?

(a) Only (i)
(b) (i), (ii)
(c) (ii), (iii)
(d) (i), (iii)

151. The correct sequence of levels forming the structural hierarchy is :

(a) Organ, organ system, cellular, chemical, tissue, organismal;
(b) Chemical, cellular, tissue, organismal, organ, organ system;
(c) Chemical, cellular, tissue, organ, organ system, organismal;
(d) Organismal, organ system, organ, tissue, cellular, chemical.

152. Which of the following is a major functional characteristic of all organisms?

(a) Movement,
(b) Growth,
(c) Metabolism,
(d) All of these.

153. Which ventral cavity subdivision has no bony protection?

(a) Thoracic cavity
(b) Abdominal cavity
(c) Pelvic Cavity.

154. A man is behaving abnormally, and his physician suspects that he has a brain tumor. Which of the following medical imaging devices would best localize the tumor in the man's brain?

(a) MRI

1. Hormonal 2. Humoral
3. Neural 4. Calcium Ions.

Choose the correct option (s) from those given below:

(a) 1 & 2 Only
(b) 2 and 4 Only
(c) 1 & 3 Only
(d) 4 Only

165. The anterior pituitary secretes all but

(a) Antidiuretic hormone
(b) Growth hormone
(c) Gonadotropins
(d) TSH.

166. A hormone not involved in sugar metabolism is:

(a) Glucagon
(b) Cortisone
(c) Aldosterone
(d) Insulin.

167. A hypodermic injection of epinephrine would

(a) Increase heart rate, increase blood pressure dilate the bronchi of the lungs, and increase peristalsis,

(b) Decrease heart rate, decrease blood pressure, constrict the bronchi, blood pressure, constrict the bronchi, and increase peristalsis,

(c) Decrease heart rate, increase blood pressure, constrict the bronchi, and decrease peristalsis,

(d) Increase heart rate, increase blood pressure, dilate the bronchi, and decrease peristalsis.

168 Testosterone is to the male as what hormone is to the female?

(a) Luteinizing hormone
(b) Progesterone
(c) Estrogen
(d) Prolactin.

169. If anterior pituitary secretion is deficient in a growing child, the child will

(a) Develop acromegaly
(b) Become a dwarf but have fairly normal body proportions
(c) Mature sexually at an earlier than normal age
(d) Be in constant danger of becoming dehydrated.

170. The posterior pituitary is not really an endocrine gland because;

3. ATP synthesis had ceased and cross-bridge detachment in the muscle became impossible.

4. Actin and Myosin protein of muscles became irreversibly cross-linked, producing rigor mortis.

Choose the correct option (s) from those given below:

(a) 3 & 4 only
(b) 4 Only
(c) 3 Only
(d) 1 & 2 Only

161. The neuropeptides that act as natural opiates are:

(a) Substance P
(b) Somatostatin
(c) Cholecystokinin
(d) Enkephalins.

162. General and local anesthetics block action potential generation, thereby rendering the nervous system quiescent while surgery is performed. What specific process do anesthetics impair?

1. It activates the inhibitory CNS receptors
2. It decreases the rate of depolarization and depolarization of excitable membranes.
3. It inhibits voltage gated sodium channels.
4. It activates the excitatory CNS receptors.

Choose the correct option (s) from those given below:

(a) 1,2 & 3 only
(b) 2, 3 & 4 only
(c) All of the above
(d) None of the above

163. The brain is protected by:

1. Bone
2. Meninges
3. Cerebrospinal fluid
4. Blood-brain barrier

Choose the correct option (s) from those given below:

(a) 1 Only
(b) 2 Only
(c) None of the above
(d) All of the above

164 The major stimulus for release of parathyroid hormone is:

(c) 1,3 & 4 Only
(d) All of the above

183. Sita went to Swiss Alps and stayed there for two months. There she developed "pink" complexion and on examination it was found that her red blood cell count was higher than normal. What is she suffering from?

(a) Anemia
(b) Polycythemia
(c) Leukemia
(d) Thrombocytopenia

184. When the semilunar valves are open, which of the following are occurring?

1. Coronary arteries fill
2. AV valves are closed
3. Ventricles are in systole
4. Ventricles are in diastole
5. Blood enters aorta
6. Blood enters pulmonary arteries
7. Atria contract

Choose the correct option(s) from those given below:

(a) 2,3,5,6 (b) 1,2,3,7
(c) 1,3,5,6 (d) 2,4,5,7

185. An ECG provides information about

(a) Cardiac output
(b) Movement of the excitation wave across the heart
(c) Coronary circulation
(d) Valve impairment

186. The fact that the left ventricular wall is thicker than the right reveals that it

(a) Pumps a greater volume of blood
(b) Pumps blood against greater resistance
(c) Expands the thoracic cage
(d) Pumps blood through a smaller valve.

187. Consider the following statements about the heart .

1. Action potentials are conducted from cell to cell across the myocardium via gap junctions
2. The SA node sets the pace for the heart as a whole
3. Spontaneous depolarization of cardiac cells can occur in the absence of nerve stimulation
4. Cardiac muscle can continue to contract for long periods of time in the absence of

oxygen.

Choose the correct option (s) from those given below:

(a) All of the above(b) 1,3,4 only

(c) 1,2,3 only(d) 2,3 only

188. Freshly oxygenated blood in the heart is first received by the :

(a) Right atrium(b) Left atrium

(c) Right ventricle(d) Left ventricle

189. Mrs. Grover, a 52- year old women was aroused in the middle of the night by severe chest pain. Her skin was pale, cold & moist and sounds were heard over the lower regions of both lungs. What is her clinical disorder?

(a) Myocardial infarction

(b) Ischemia

(c) Arrhythmia

(d) Congestive heart failure

190. Which of the following tissues is mainly responsible for vasoconstriction?

(a) Elastic tissue,

(b) Smooth muscle,

(c) Collagenic tissue,

(d) Adipose tissue.

191. Arterial blood pressure increases in response to:

(a) Increasing stroke volume,

(b) Increasing heart rate,

(c) Arteriosclerosis

(d) All of these.

192. Lymphatic vessels

(a) Serve as sites for immune surveillance,

(b) Filter lymph,

(c) Transport leaked plasma proteins and fluids to the cardiovascular system,

(d) Are represented by vessels that resemble arteries, capillaries, and veins.

193. The lymphoid organ that functions primarily during youth and then begins to atrophy is the

(a) Spleen

(b) Thymus

(c) Palatine tonsils

(d) Bone marrow.

194. A friend tells you that she has tender, swollen “glands” along the left side of the front of her neck. Exactly what are her swollen “glands”?

(a) Thyroid
(b) Parathyroid
(c) Lymph nodes
(d) Larynx.

195. All of these are considered nonspecific body defenses except
(a) Complement
(b) Phagocytosis
(c) Anti-bodies
(d) Lysozyme.

196. Antibodies released by plasma cells are involved in
(a) Humoral immunity
(b) Immediate hypersensitivity reactions
(c) Autoimmune disorders
(d) All of the above.

197. Which antibody class is abundant in plasma :
(a) IgA (b) IgD
(c) IgE(d) IgG.

198. Cells that can directly attack target cells included all of the following except
(a) Macrophages
(b) Cytotoxic T cells.
(c) Helper T cells
(d) Natural killer cells.

199. Some people with a deficit of IgA exhibit recurrent respiratory tract infection because :
1. It is found primarily in mucus and other sections that bathe body surface.
2. It is involved in allergies.
3. It is the most abundant antibody in the body.
4. It is the first antibody class that is released to the blood by plasma cells.

Choose the correct code (s) from those given below:
(a) 1 Only
(b) 2 & 3 Only
(c) 1 & 2 Only
(d) All the above

200. Following the removal of his larynx, an individual would
(a) Be unable to speak
(b) Be unable to cough
(c) Have difficulty in swallowing,

(d) Be in respiratory difficulty or arrest.

201. When the inspiratory muscles contract:

(a) The size of the thoracic cavity is increased in diameter,

(b) The size of the thoracic cavity is increased in length

(c) The volume of the thoracic cavity is decreased

(d) The size of the thoracic cavity is increased in both length and diameter.

202. The nutrient blood supply of the lungs is provided by

(a) The pulmonary arteries

(b) The aorta

(c) The pulmonary veins

(d) The bronchial arteries.

203. Which of the following has the greatest stimulating effect on the respiratory center in the brain?

(a) Oxygen

(b) Carbon dioxide

(c) Calcium

(d) Willpower.

204. In mouth-to-mouth artificial respiration, the rescuer blows air from his or her own respiratory system into that of the victim. Which of the following statement(s) are correct?

1. Expansion of the victim’s lungs is brought about by blowing air in at higher than atmospheric pressure (positive pressure breathing.)

2. During inflation of the lungs, the intrapleural pressure increases.

3. This technique will not work if the victim has a hole in the chest wall, even if the lungs are intact.

4. Expiration during this procedure depends on the elasticity of the alveolar and thoracic walls.

Choose the correct option(s) from the following codes given below:

(a) All of the above

(b) 1,2 and 4 only

(c) 1,2 and 3 only

(d) 1 and 4 only

205. A baby holding its breath will

(a) Have brain cells damaged because of low blood oxygen levels.

(b) Automatically start to breathe again when the carbon dioxide levels in the blood reach a high enough value.

(c) Suffer heart damage because of increased pressure in the carotid sinus and aortic

(c) Formation of most structural materials
(d) As a source of quick energy

220. A person has been on a hunger strike for seven days, compared to normal, he has
(a) Increased release of fatty acid from adipose tissue, ketosis, and ketonuria
(b) Elevated glucose concentration in the blood
(c) Increased plasma insulin concentration
(d) Increased glycogen synthetase (enzyme) activity in the liver

221. Three days after removal of the pancreas from an animal, the researcher finds a persistent increase in
(a) Acetoacetic acid concentration in the blood
(b) Urine volume
(c) Blood glucose
(d) All of the above

222. Which of the following yields the greatest caloric value per gram?
(a) Fats
(b) Proteins
(c) Carbohydrates
(d) All are equal in caloric value.

223. Glucose is not normally found in the urine because it
(a) Does not pass through the walls of the glomerulus
(b) Is kept in the blood by colloid osmotic pressure
(c) Is reabsorbed by the tubule cells
(d) Is removed by the body cells before the blood reaches the kidney

224. Filtration at the glomerulus is directly related to
(a) Water reabsorption
(b) Arterial blood pressure
(c) Capsular hydrostatic pressure
(d) Acidity of the urine.

225. Patients suffering from hypertension are prescribed diuretics, because:
1. They cause the dilation of blood vessels
2. They increase the rate of urine formation
3. They decrease the blood volume
4. They relax the brain

Choose the correct option (s) from those given below:
(a) 1 & 2 only
(b) 2 & 3 only
(c) 1 & 3 only

arch area

(d) Be called a “blue baby”.

206. Carbohydrates are acted on by

(a) Peptidases, trypsin, and chymotrypsin

(b) Amylase, maltase and sucrase

(c) Lipases

(d) Peptidases, lipases, and galactase.

207. The digestive juice product containing enzymes capable of digesting all four major foodstuff categories is

(a) Pancreatic

(b) Gastric

(c) Salivary

(d) Biliary

208. The vitamin associated with calcium absorption is

(a) A

(b) K

(c) C

(d) D

209. Someone has eaten a meal of buttered toast, cream, and eggs. Which of the following would you expect to happen?

(a) Compared to the period shortly after the meal, gastric motility and secretion of HCl decrease when the food reaches the duodenum

(b) Gastric motility increases even as the person is chewing the food .

(c) Fat will be emulsified in the duodenum by the action of bile

(d) All of these

210. The site of production of GIP and cholecystokinin is

(a) The stomach

(b) The small intestine

(c) The pancreas

(d) The large intestine

211. Which of the following is not a characteristic of the large intestine?

(a) It is divided into ascending, transverse and descending portions.

(b) It contains abundant bacteria, some of which synthesize certain vitamins.

(c) It is the main absorptive site.

(d) It absorbs much of the water and salts remaining in the wastes.

212. The gallbladder

(a) Produces bile

Which of the statement(s) given above is/are true?

(a) None of the above
(b) 1 and 2 only
(c) 1 only
(d) 2 and 3 only

233. Consider the following statements:

1. The sugar present in RNA is glucose.
2. Sucrose is an artificial sweetener.
3. The urine samples of diabetic patients contain glucose

Which of the statements given above is/are not true?

(a) 1 and 3
(b) 1 and 2
(c) 3 only
(d) 1 only

234. The function of a sedative is to

(a) Calm anxiety
(b) Cause a temporary loss of sensation
(c) Compel the user to sleep
(d) Elevate the mood

235.The hallucinogenic chemical commonly known as “Grass” or “Hash” is:

(a) LSD
(b) Marihuana
(c) Mescaline
(d) Methaqualone

236. Consider the following elements:

1. Carbon 2. Nitrogen
3. Hydrogen 4. Oxygen

Which elements does sugar contain?

(a) 1, 3 and 4
(b) 1, 2 and 3
(c) 1 and 3
(d) 1 and 4

237. The smallest bone in the human body is:

(a) Malleus
(b) Stapes
(c) Incus
(d) All of these

(b) Is attached to the pancreas
(c) Stores and concentrates bile
(d) Produces hormone Secretin.

213. The protein molecule will be digested by enzymes secreted by
(a) The mouth, stomach, and colon
(b) The stomach, liver and small intestine
(c) The small intestine, mouth and liver
(d) The pancreas, small intestine and stomach

214. The protein molecule must be digested before it can be transported to and utilized by the cells because
(a) Protein is only useful directly
(b) Protein has a low pH
(c) Proteins in the circulating blood produce an adverse osmotic pressure,
(d) The protein is too large to be readily absorbed.

215. Fatty stools result from the absence of
(a) Gastric secretion
(b) Chylomicrons
(c) Bile Salts
(d) Salivary secretion.

216. Which of the following reactions would liberate the most energy?
(a) Complete oxidation of a molecule of sucrose to CO2 and water
(b) Conversion of a molecule of ADP to ATP
(c) Respiration of a molecule of glucose to lactic acid
(d) Conversion of a molecule of glucose to carbon dioxide and water.

217. Which of the following best defines cellular respiration?
(a) Intake of carbon dioxide and output of oxygen by cells
(b) Excretion of waste products
(c) Inhalation of oxygen and exhalation of carbon dioxide
(d) Oxidation of substances by which energy is released in usable form to the cells.

218. Metabolic rate is relatively low in :
(a) Youth
(b) Physical exercise
(c) Old age
(d) Fever.

219. Amino acids are essential to the body for all the following except
(a) Production of some hormones
(b) Production of antibodies

Which of the above statement/statements is/are true?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

245.Smokers suffer chronically from the effects of

(a) Carbon dioxide
(b) Nitrogen dioxide
(c) Carbon monoxide
(d) Sulphur dioxide

246.Carcinogenesis can be caused by

1. X-rays 2. Dyes and paints
3. Benzene 4. Soot and tar

Select the correct answer using the codes given below:

(a) 1, 2, 3 and 4
(b) 1, 3 and 4
(c) 1, 2 and 4
(d) 1, 2 and 3

247. The average upper limit of salt intake recommended per person per day by WHO for healthy life is:

(a) 3 grams
(b) 5 grams
(c) 7 grams
(d) 8 grams

248. Which of the following statements are correct for the human body?

1. Sodium ions are found inside cells.
2. Potassium ions are found inside cells.
3. Magnesium ions are found inside cells.
4. Calcium ions are found outside cells.

Select the correct answer using the codes given below:

(a) 2 and 4
(b) 1 and 4
(c) 1, 3 and 4
(d) 2, 3 and 4

249 Study the following statements and select the correct answer from the codes given below the statements:

1. Cholesterol is the most abundant lipid in some of the human cell membranes.

(d) None of the above

226. Body water content is greater in
   (a) Infants
   (b) Young
   (c) Adult
   (d) Elderly adults

227. The sex of a child is determined by
   (a) The sex chromosome contained in the sperm,
   (b) The sex chromosome contained in the oocyte,
   (c) The number of sperm fertilizing the oocyte
   (d) The position of the fetus in the uterus.

228. A drug that “reminds the pituitary” to produce gonadotropins might be useful as :
   (a) A contraceptive
   (b) A diuretic
   (c) A fertility drug
   (d) An abortion stimulant.

229. The term urinogenital system is more applicable to males than to females, because :
   (a) Males have common passage for semen and urine.
   (b) Males have common system for both reproduction and urine formation.
   (c) Males have common urinary and genital structures.

230. The zygote contains chromosome from
   (a) The mother only
   (b) The father only
   (c) Both the mother and father, but half from each
   (d) Each parent and synthesizes others.

231. Identical twins result from the fertilization of :
   (a) One ovum by one sperm
   (b) One ovum by two sperms
   (c) Two ova by two sperms
   (d) Two ova by one sperm

232. Consider the following statement about cleavage. It is an embryonic event that mainly involves mitotic divisions, but cleavage is not the same as mitosis because ,during cleavage :

1. Enormous volume of cytoplasm is divided into several nucleated cells.

2. Blastomeres do not increase in size as gap or growth period during cell cycle is absent.

3. Ratio of volume of nucleus to cytoplasm is very high initially.

238. A woman of blood group AB when married to an O group man will never have an AB group child. What could be the reason/s?

(a) Blood group O gene is dominant over blood group AB.
(b) Blood group O individuals carry antigens against AB.
(c) Group O individuals carry antibodies that abort AB faetuses at a very early stage.
(d) Group O individuals carry no antigens for A or B blood group.

239. ‘Delhi boil’ or Oriental sore is a protozoan disease transmitted by the bite of:

(a) Aedes mosquito
(b) Sandfly
(c) Tsetse fly
(d) Reduvid bug

240.The material used in hospitals for setting fractured bones in the right position contains

(a) Calcium phosphate
(b) Calcium oxide
(c) Calcium sulphate
(d) Calcium silicate

241.The earth’s atmosphere at the time of the origin of life contained:

(a) Ethane, methane, nitrogen and oxygen
(b) Carbon-dioxide, methane, oxygen and ammonia
(c) Ammonia, carbon-dioxide, methane and water vapour
(d) Carbon-dioxide, methane, oxygen and water vapour

242.Out of all the primates, the animal that lacks resemblance to the humans is:

(a) Slow Loris
(b) Orangutan
(c) Hoolock Gibbon
(d) Lemur

243.Which of the following will indicate that the climate of a region has warmed in the past?

(a) Coral reefs having their bases at depth of more than 50 fathoms
(b) Raised beaches with steep slopes to the sea
(c) Fossils of broad leaved-trees in area of needle-leaf forests
(d) Coral reefs having their bases at depths of less than 30 fathoms

244. Consider the following statements:

1. The Kaziranga National Park is famous for one horned rhino.
2. This animal is best adapted to the local environment and has replaced all other large herbivores.

2. Human body cells can synthesize cholesterol.
3. More than 50% of bacterial cell membranes are composed of cholesterol.
4. Presence of cholesterol in cell membranes tends to increase its fluidity.

Which of the above statement/s is/are correct?

(a) 1 and 3
(b) Only 3
(c) 1, 2 and 4
(d) Only 4

250. Consider the following statements:

1. Calcitonin is secreted by the cells of parathyroid gland.
2. Calcitonin decreases the level of calcium in the blood.
3. It decreases the rate of calcium excretion.
4. It protects against calcium loss from the skeleton.

Which of the statements given above are true?

(a) 1, 2
(b) 1, 2, 3
(c) 1, 2, 3, 4
(d) 2, 3, 4

251.Consider the following statements:

1. Human liver is a red-brown soft spongy organ located at the top of the abdomen on the left side of the body just below the diaphragm
2. The diaphragm, a sheet of muscle tissue, separates the lungs from the abdominal organs
3. The lower part of the rib cage covers the liver, protecting it from injury
4. In a healthy adult, the liver weights about 2-3 kg.

Which of the above statements are true?

(a) 1, 2
(b) 2, 3
(c) 2, 3, 4
(d) 1, 2, 3, 4

252. Diet deficient in ripe yellow fruits, carrots, leafy vegetables, pumpkin, spinach, yellow squash and liver will cause the deficiency disease:

(a) Beriberi
(b) Ariboflavinosis
(c) Dermatitis and gastroenteritis
(d) Night-blindness and xerophthalmia (dry eye)

253.Mutagens are chemicals that affect the:

(a) Hereditary pattern
(b) Enzyme action
(c) Nerves
(d) Sense of judgment

254.Consider the following statements:

1. Chikungunya is also called breakbone fever and is caused by CHIK V virus, an alphavirus.

2. It is transmitted by the mosquito Aedes aegypti

3. It has symptoms similar to dengue fever with joint pain, intense headache, stiffness of joints, muscular pain, fatigue, irritation of eyes and blurring vision, nausea, vomiting and petechial rash.

4. The fever will subside early but joint pain may remain for many months or even years. The correct response is

Code:

(a) 1, 2, 3
(b) 2, 3, 4
(c) 1, 2, 3, 4
(d) 3, 4

255.Sun is the ultimate source of energy that sustains all life on earth because:

1. But for the heat energy from the sun, our earth would have been too cold for life to exist

2. The food that we consume, whether we are vegetarian or non-vegetarian, is produced making use of solar energy

3. The petrol and diesel that runs our transport system was also produced by the use of solar energy millions of years ago.

Which of the above is/are the correct explanation/s?

(a) 1 Only
(b) 2 Only
(c) 1 and 2
(d) 1, 2, and 3

256.In a pathbreaking open heart bypass surgery conducted by Dr Ramakant Panda on a patient with 90% blockage in both the coronary arteries, the number of separate bypass grafts created and then connected to the blocked coronary artery to restore the free flow of blood to the heart to give new lease of life to the patient were:

(a) 7
(b) 9
(c) 10

(d) 12

257.Consider the following statements:

1. All termites eat wood as cellulose in its various forms as plant fibre.
2. Termites rely primarily upon symbiotic protozoa such as Trichonympha which, in turn, depend on symbiotic bacteria embedded on their surface.
3. This symbiotic bacterium produces necessary enzymes for cellulose digestion.
4. The end products of cellulose digestion are glucose, acetate and butyrate that are used as energy sources by termites.

Which of the above statements are true?

(a) 1, 2
(b) 1, 2, 3
(c) 1, 3, 4
(d) 1, 2, 3, 4

258.The higher prevalence of diabetes mellitus in South India is due to

(a) Overdependence on rice
(b) Coconut oil
(c) Genetic predisposition
(d) All of these

ANSWER KEY

1. (c) 2. (a) 3. (c) 4 (c) 5. (c) 6. (a)
7. (d) 8. (a) 9. (d) 10. (d) 11. (d) 12. (d)
13. (d) 14. (d) 15. (a) 16. (b) 17. (b) 18. (b)
19. (d) 20. (d) 21. (a) 22. (b) 23. (d) 24. (c)
25. (d) 26. (c) 27. (d) 28. (d) 29. (a) 30. (b)
31. (c) 32. (c) 33. (b) 34. (a) 35. (d) 36. (d)
37. (d) 38. (d) 39. (b) 40. (c) 41. (d) 42. (d)
43. (a) 44. (a) 45. (c) 46. (b) 47. (a) 48. (a)
49. (b) 50. (b) 51. (b) 52. (d) 53. (a) 54. (d)
55. (c) 56. (d) 57. (c) 58. (b) 59. (a) 60. (b)
61. (d) 62. (a) 63. (d) 64. (b) 65. (c) 66. (b)
67. (d) 68. (d) 69. (b) 70. (c) 71. (a) 72. (b)
73. (c) 74. (a) 75. (c) 76. (d) 77. (a) 78. (b)
79. (d) 80. (c) 81. (a) 82. (b) 83. (b) 84. (d)
85. (a) 86. (b) 87. (b) 88. (a) 89. (c) 90. (d)
91. (c) 92. (c) 93. (a) 94. (c) 95. (d) 96. (c)

97. (d) 98. (d) 99. (c) 100. (c) 101. (c) 102. (c)
103. (d) 104. (c) 105. (d) 106. (b) 107. (d) 108. (d)
109. (a) 110. (d) 111. (a) 112. (d) 113. (b) 114. (c)
115. (d) 116. (b) 117. (d) 118. (d) 119. (c) 120. (d)
121. (d) 122. (b) 123. (c) 124. (d) 125. (a) 126. (b)
127. (d) 128. (b) 129. (d) 130. (c) 131. (c) 132. (d)
133. (d) 134. (b) 135. (c) 136. (a) 137. (c) 138. (c)
139. (d) 140. (a) 141. (c) 142. (c) 143. (d) 144. (b)
145. (a) 146. (d) 147. (c) 148. (b) 149. (a) 150. (c)
151. (c) 152. (d) 153. (b) 154. (a) 155. (d) 156. (b)
157. (b) 158. (d) 159. (c) 160. (a) 161. (d) 162. (a)
163. (d) 164. (b) 165. (c) 166. (c) 167. (d) 168. (c)
169. (b) 170. (a) 171. (c) 172. (b) 173. (c) 174. (c)
175. (d) 176. (b) 177. (d) 178. (a) 179. (a) 180. (d)
181. (c) 182. (c) 183. (b) 184. (a) 185. (b) 186. (b)
187. (c) 188. (b) 189. (a) 190. (b) 191. (d) 192. (c)
193. (b) 194. (c) 195. (c) 196. (d) 197. (d) 198. (c)
199. (a) 200. (a) 201. (d) 202. (d) 203. (b) 204. (b)
205. (b) 206. (b) 207. (a) 208. (d) 209. (d) 210. (b)
211. (c) 212. (c) 213. (d) 214. (d) 215. (c) 216. (a)
217. (d) 218. (c) 219. (d) 220. (a) 221. (d) 222. (a)
223. (c) 224. (b) 225. (b) 226. (a) 227. (a) 228. (c)
229. (a) 230. (c) 231. (a) 232. (b) 233. (b) 234. (a)
235. (b) 236. (a) 237. (b) 238. (d) 239. (b) 240. (c)
241. (c) 242. (d) 243. (a) 244. (a) 245. (c) 246. (a)
247. (b) 248. (d) 249. (c) 250. (d) 251. (b) 252. (d)
253. (a) 254. (b) 255. (d) 256. (c) 257. (b) 258. (d)

QUESTIONS FROM RECENT YEARS' PAPERS

1. Regular intake of fresh fruits and vegetables is recommended in the diet since they are a good source of antioxidants.

How do antioxidants help a person maintain health and promote longevity?

(a) They activate the enzymes necessary for vitamin synthesis in the body and help prevent vitamin deficiency

(b) They prevent excessive oxidation of carbohydrates, fats and proteins in the body and help avoid unnecessary wastage of energy

(c) They neutralise the free radicals produced in the body during metabolism

(d) They activate certain genes in the cells of the body and help delay the ageing process(2011)

2.At present, scientists can determine the arrangement or relative positions of genes or DNA sequences on a chromosome.

How does this knowledge benefit us?

1. It is possible to know the pedigree of livestock.
2. It is possible to understand the causes of all human diseases.
3. It is possible to develop disease-resistant animal breeds.

Which of the statements given above is/are correct?

(a) 1 and 2 only

(b) 2 only

(c) 1 and 3 only

(d) 1, 2 and 3(2011)

3.A married couple adopted a male child. A few years later, twin boys were born to them. The blood group of the couple is AB positive and O negative. The blood group of the three sons is A positive, B positive, and O positive.

The blood group of the adopted son is

(a) O positive

(b) A positive

(c) B positive

(d) Cannot be determined on the basis of the given data(2011)

4. With reference to 'stem cells', frequently in the news, which of the following statements is/are correct?

1. Stem cells can be derived from mammals only.
2. Stem cells can be used for screening new drugs.
3. Stem cells can be used for medical therapies.

Select the correct answer using the codes given below:

(a) 1 and 2 only

(b) 2 and 3 only

(c) 3 only

(d) 1, 2 and 3(2012)

5. With reference to the scientific progress of ancient India, which of the statements given below are correct?

1. Different kinds of specialized surgical instruments were in common use by 1st century AD.

2. Transplant of internal organs in the human body had begun by the beginning of 3rd century AD.

3. The concept of sine of an angle was known in 5th century AD.

4. The concept of cyclic quadrilaterals was known in 7th century AD,

Select the correct answer using the codes given below:

(a) 1 and 2 only

(b) 3 and 4 only

(c) 1, 3 and 4 only

(d) 1, 2, 3 and 4

(2012)

6. Which one of the following sets of elements was primarily responsible for the origin of life on the Earth?

(a) Hydrogen, Oxygen, Sodium

(b) Carbon, Hydrogen, Nitrogen

(c) Oxygen, Calcium, Phosphorus

(d) Carbon, Hydrogen, Potassium(2012)

7. Which of the following statements is/are correct?

1. Viruses lack enzymes necessary for the generation of energy.

2. Viruses can be cultured in any synthetic medium.

3. Viruses are transmitted from one organism to another by biological vectors only.

Select the correct answer using the codes given below:

(a) 1 only

(b) 2 and 3 only

(c) 1 and 3 only

(d) 1, 2 and 3(2013)

8. With reference to the food chains in ecosystems, which of the following kinds of organism is/are known as decomposer organism/organisms?

1. Virus 2. Fungi

3. Bacteria

Select the correct answer using the codes given below:

(a) 1 only

(b) 2 and 3 only

(c) 1 and 3 only

(d) 1, 2 and 3(2013)

9. The most important fishing grounds of the world are found in the regions where.

(a) Warm and cold atmospheric currents meet

(b) Rivers drain out large amounts of freshwater into the sea

(c) Warm and cold oceanic currents meet

(d) Continental shelf is undulating

(2013)

10. Improper handling and storage of cereal grains and oilseeds result in the production of toxins known as aflatoxins which are not generally destroyed by normal cooking process. Aflatoxins are produced by

(a) Bacteria

(b) Protozoa

(c) Moulds

(d) Viruses(2013)

11. With references to food chains in ecosystems. Consider the following statements:

1. A food chain illustrates the order in which a chain of organisms feed upon each other.

2. Food chains are found within the population of a species.

3. A food chain illustrates the numbers of each organism which are eaten by others.

Which of the statement given above is/are correct?(2013)

(a) 1 only

(b) 1 and 2 only

(c) 1, 2 and 3

(d) None

12. Which of the following adds/add nitrogen to the soil?

1. Excretion of urea by animals

2. Burning of coal by man

3. Death of vegetation

Select the correct answer using the codes given below.

(a) 1 only

(b) 2 and 3 only

(c) 1 and 3 only

(d) 1, 2 and 3(2013)

13. Which of the following diseases can be transmitted from one person to another through tattooing?

1. Chikungunya 2. Hepatitis B

3. HIV-AIDS

Select the correct answer using the codes given below.

(a) 1 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3(2013)

14. Which one of the following terms describes not only the physical space occupied by

an organism, but also it functional role in the community of organisms?

(a) Ecotone
(b) Ecological niche
(c) Habitat
(d) Home range(2013)

15. Consider the following minerals :

1. Calcium
2. Iron
3. Sodium

Which of the minerals given above is/are required by human body for the contraction of muscles?

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3(2013)

16. Recombinant DNA technology (Genetic Engineering) allows genes to be transferred

1. Across different species of plants
2. From animals to plants
3. From microorganisms to higher organisms

Select the correct answer using the codes given below:

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3(2013)

17. Consider the following animals :

1. Sea Cow
2. Sea horse
3. Sea lion

Which of the above is/are mammal/mammals?

(a) 1 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3(2013)

18. In the grasslands, trees do not replace the grasses as a part of an ecological succession because of

(a) Insects and fungi
(b) Limited sunlight and paucity of nutrients

(c) Water limits and fire

(d) None of the above(2013)

19. Which one of the following is the correct sequence of ecosystems in the order of decreasing productivity?

(a) Oceans, lakes, grassland, mangroves

(b) Mangroves, oceans, grasslands, lakes

(c) Mangroves, grasslands, lakes, oceans

(d) Oceans, mangroves, lakes, grasslands

(2013)

ANSWER KEY

1. (c) 2. (c) 3. (a) 4. (b) 5. (c) 6. (b)
7. (a) 8. (b) 9. (c) 10. (c) 11. (a) 12. (d)
13. (b) 14. (b) 15. (a) 16. (d) 17. (b) 18. (b)
19. (c)

SECTION–III

PLANT WORLD

CHAPTER ELEVEN

PLANT STRUCTURE, FUNCTION AND REPRODUCTION

B.11.1 PLANT BODY

Angiosperms are classified as annuals, biennials, or perennials, depending upon the length of their life cycle. Most flowering plants belong to one of two major groups (Fig. B.11.1).

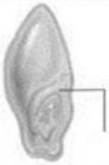
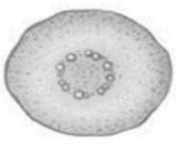
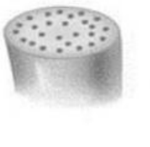
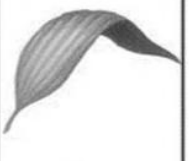
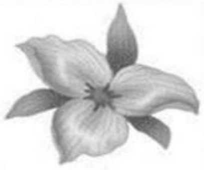
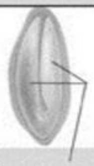
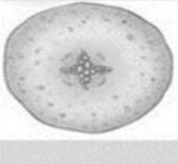
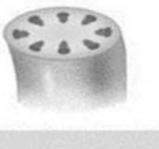
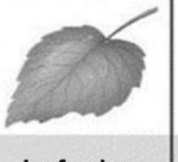
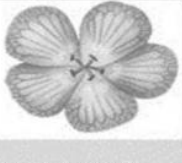
	Seed	Root	Stem	Leaf	Flower
Mono-cots					
Feature	**one cotyledon**	**root xylem and phloem in a ring**	**vascular bundles scattered in stem**	**leaf veins form a parallel pattern**	**flower parts in threes and multiples of three**
Eudi-cots					
Feature	**Two cotyledons**	**root phloem between arms of xylem**	**vascular bundles in a distinct ring**	**leaf veins form a net pattern**	**flower parts in four or fives and their multiples**

Figure B.11.1

The comparison between Monocots and Eudicots

The Root

The **root system** anchors the plant in its place and provides nutrition. The extreme branching of plant roots and their high area to volume ratio allow them to absorb water and mineral nutrients from the soil (Fig B.11.2). Roots are organs specialised for anchorage, absorption, storage and conduction. The three main types of roots present in the plants are:

- **Tap root**: Most of the Dicots and gymnosperms have tap root system: a single, large, deep growing primary root having less prominent lateral roots. The tap root itself often functions as a nutrient storage organ, as in carrots.

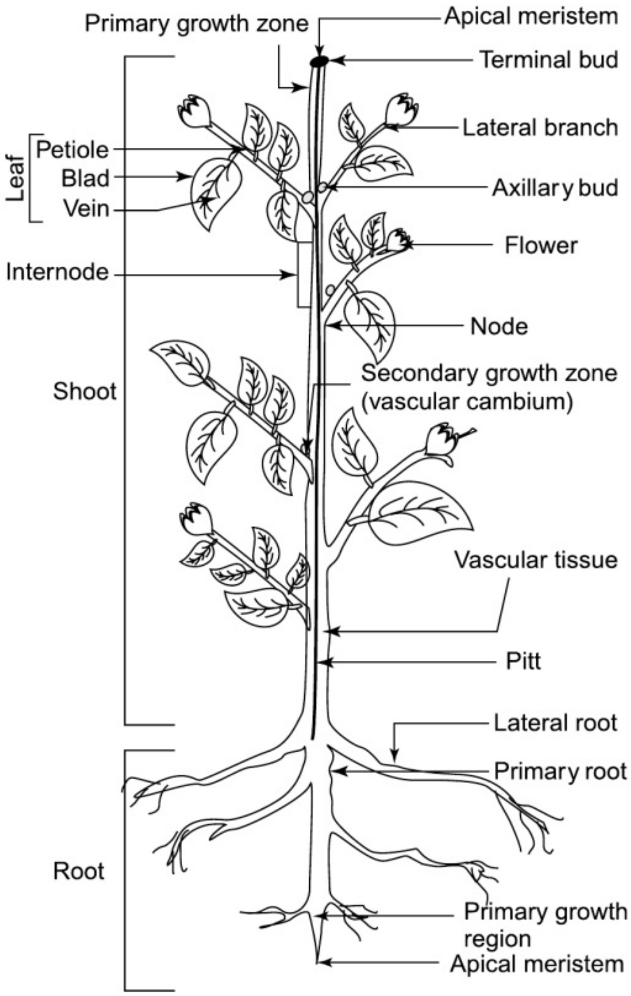


Figure B.11.2

An angiosperm plant showing different plant parts. The root system is underground; the shoot system, consisting of leaves, stem and flowers, is above the ground

- **Fibrous root**: Monocots and Eudicots have a fibrous root system, which is composed of numerous thin roots that are all roughly equal in diameter. Many fibrous root systems have a large surface area for the absorption of water and minerals. A fibrous root system clings to the soil very well. The fibrous root system of the grass protects steep hill sides runoff from rain and prevents soil erosion.
- **Adventitious root**: Some plants have adventitious roots**.** These roots arise above ground from points along the stem; some even arise from the leaves. These roots enable the cuttings to establish itself in the soil as a new plant. Such cuttings are a form of **asexual reproduction**, also called vegetative reproduction in plants. Some plants—corn, banyan trees, use adventitious roots as **prop root** to support the shoot.

Root modifications include **aerial, aerating** and **fleshy root**. In some plants like onion have bulbous root in which many fibres like roots originate from one head. Carrot and Radish have tuberous roots in which a number of small or scattered fibres are present.

The Shoot

The **shoot system** of a plant consists of *stems, leaves* and *flowers*. The leaves are the chief organ of photosynthesis. The stem exposes the leaves to the sun and provides connections for the transport of material between roots and leaves. The point of attachment of the leaf on the stem is called **node**. The stem between two nodes is referred as **internodes**. *Stem bears buds, leaves and flowers.* The central function of the stem is to elevate and support the reproductive organs (flowers) and the photosynthetic organ (leaves). In some plants stem arises from the root and supports the flower but not the leaf, these are known as **scape,** e.g., *Aloe*. The young stem is usually green and is capable of photosynthesis, but it is not the principal site of photosynthesis.

A **bud** is an embryonic shoot. A stem bears leaves at its nodes and in the angle (axil) where each leaf meets, a bud is present. The bud, in the axil of the leaf, it is called an **axillary bud**. When axillary bud becomes active it develops into new branches. Different species depending on the environmental conditions have different branching pattern. Cutting of branches is called **pruning**. The gardener's pruning activities makes the axillary bud to grow. Plants grown for hedges are regularly pruned so that large number of axillary bud grows and forms lateral branches.

Some stems are highly modified. The **tuber** of a potato is an underground stem. Its "eyes" are depression containing axillary bud, thus, a sprouting potato is just a branching stem. Many desert plants have enlarged, water retaining stem, e.g., the stem of *cactus* is enlarged to store water. Its leaves are reduced to spines. The **runners** of *strawberry* plants and *Bermuda* grass are horizontal stems from which roots grow at frequent intervals. The fragment having roots can be used for vegetative reproduction.

The Leaf

Leaves are the site of photosynthesis. The blade of leaf is a thin, flat structure attached to the stem by a stalk called **petiole**. In many plants, the leaf blade is held by its petiole at an angle almost perpendicular to the rays of the sun. This increases the amount of light available for photosynthesis. Some leaves track the sun over the course of the day, moving so that they constantly face the sun. A leaf may be simple or compound. Simple leaf consists of a single **blade,** whereas compound has multiple blades called **leaflets.** These leaflets are arranged along an axis radiating from a central point. In both the types of leaves (see Fig. B.11.1), the vein may be parallel to one another (as in **monocots**), or net like arrangement (as in **Eudicots**).

In some plants leaves are modified for special function. The different modifications are as:

- Food storage organ: Modified leaves serve as storage organs for energy rich molecules, as in bulbs of onion.
- Water storage: In **succulents** it stores water, the spines of cacti are also modified leaves.
- Support organ: Many plants, as in peas, have **tendrils** that support the plant by wrapping around any object or plants.

The common feature of all these three organs—root, stem and leaf, are that they all consist of three tissue systems.

Plants Tissues and Tissue System

A tissue is an organised group of cells that have common feature and that work together as a structural and function unit. Tissue in turn, is grouped into tissue systems.

Types of Plant Tissue

(i) Simple Tissues: It is a mature tissue made up of one type of cell. Most of the ground tissue in the plant body consists of simple tissue. It is of three types (Fig. B.11.3):

- **Parenchyma:** The cells of parenchyma are thin-walled and polyhedral (many sides) in shape. It has a central large vacuole. The cells of parenchyma have the capacity to divide. Because of this meristematic activity it plays an important role in regeneration and wound healing. Structurally it has different sizes and shapes. It performs many functions and depending on its role it is known by different names. The cells in which chloroplast is present are known as chlorenchyma and the cells which store air—arenchyma. The chlorenchyma is present in the mesophyll layer of leaf. The arenchyma is present in the aquatic plants, it helps the plant to float in water.
- **Collenchyma:** The cells of collenchyma are elongated. The most distinctive feature is presence of uneven thickenings in the cell wall. It provides support for young and

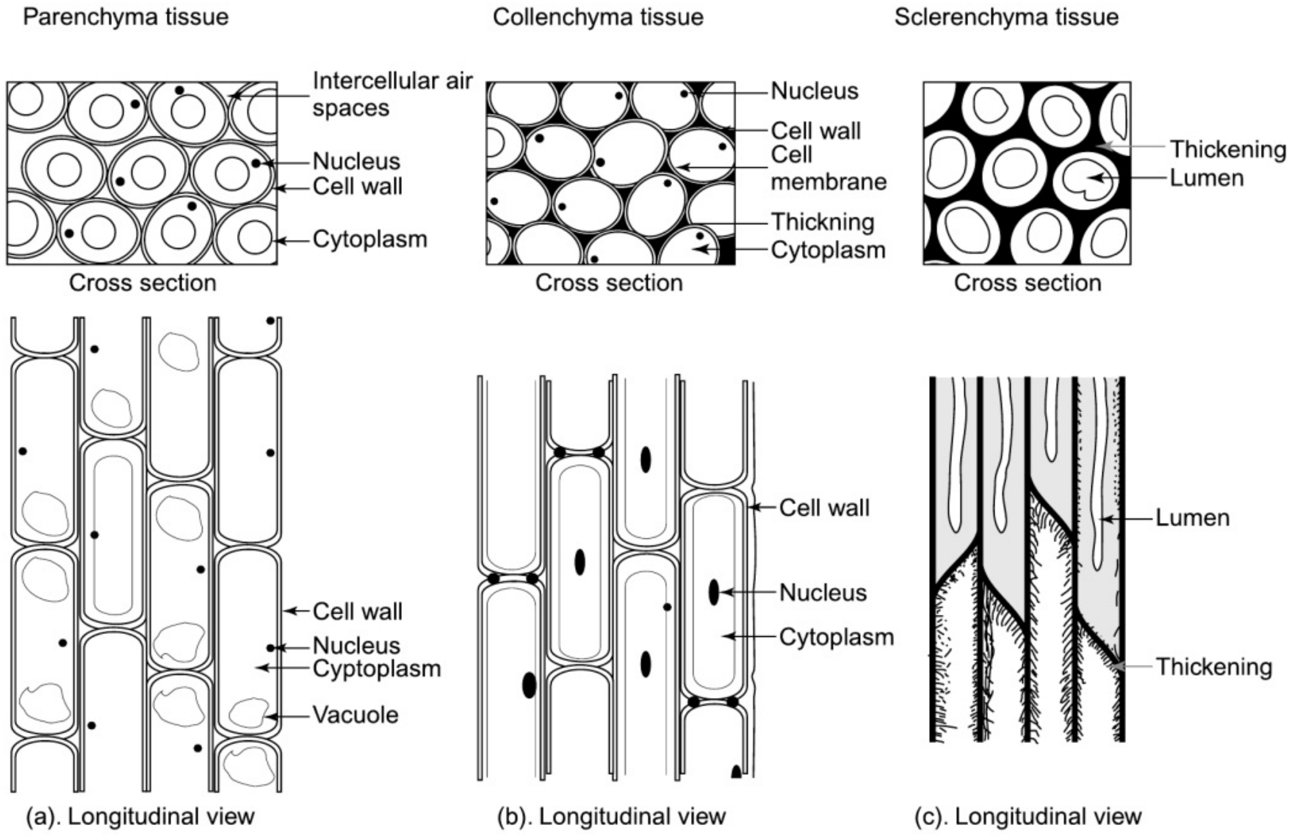

Parenchyma tissue
Collenchyma tissue
Sclerenchyma tissue
Intercellular air spaces
Nucleus
Cell wall
Cytoplasm
Cross section
Nucleus
Cell wall
Cell membrane
Thickning
Cytoplasm
Cross section
Thickening
Lumen
Cross section
Cell wall
Nucleus
Cyptoplasm
Vacuole
Cell wall
Nucleus
Cytoplasm
Lumen
Thickening
(a). Longitudinal view
(b). Longitudinal view
(c). Longitudinal view

Figure B.11.3

Simple tissues (a) Parenchyma tissue: The cells are thin-walled with intercellular spaces (b) Collenchyma tissue: The cells are elongated with thickening at angles (c) Sclerenchyma tissue: The cells are thick walled.

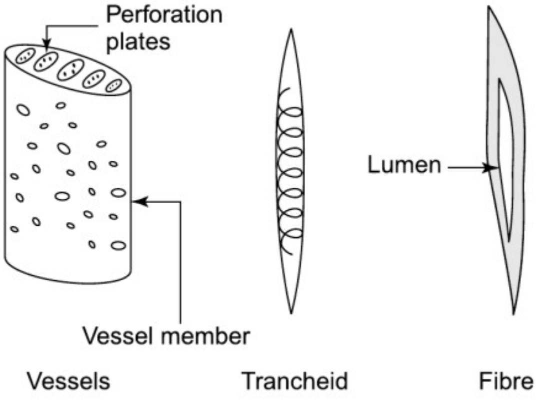
growing organs. It is present where support is required, like petiole of leaf and stems.

- **Sclerenchyma:** The cells are uniformly thick-walled (lignin is deposited) and occur in small groups. They lack protoplasts at maturity. They provide support and also protect the seeds. There are two types of sclerenchyma cells, **fibre** and **sclereids**. Fibres are long, tapered cells in the vascular tissue of root and shoot. They make economically important plant fibres, e.g., Flex fibre, Jute and Cotton. Sclereids are short cells. They may occur singly or in clumps. They make up the hard seed coat of many seeds and hard coconut shell. Isolated clumps of sclereids, called **stone cells**, in pears and some other fruits give them their gritty and hard texture. The hardness in nuts is also due to the presence of stone cell in the seed coat.

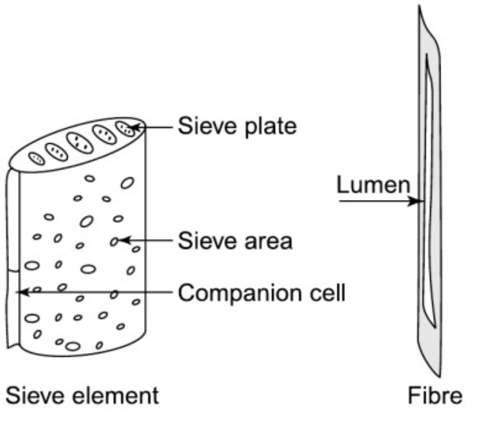
Fibres from the stems of hemp, *Cannabis sativus*, gave strength to sail ropes and rigging of sailing vessels. The durability to the Gutenberg bible, the declaration of independence, and the constitution of the United States is also due to the presence of Fibre. The original Levi's jeans were made up of hemp cloth which makes the jeans cloth durable.

(ii) Complex tissues: They are made of more than one type of cell.

- **Vascular tissue:** Xylem and phloem are vascular tissues. Xylem consists of tracheary elements, which is made up tracheids and vessel elements. Both are elongated cells, have secondary wall thickenings and lack protoplast at maturity. Vessel elements contain perforations. These perforations are the holes in the cell wall, which help in forming long, continuous column or tubes. The angiosperms contain both tracheids and vessels, while seedless vascular plant and gymnosperms have only tracheids. The tracheids do not have perforations; therefore it is less efficient in water transport. In phloem, the principal conducting cells are the sieve elements. The sieve elements are of two types, the sieve cell and sieve tube members. The sieve elements have cluster of pores known as sieve areas. In sieve cells the pores are narrow. The pore size is bigger in sieve tube members. The sieve elements have living protoplast. Sieve tube elements are associated with special parenchymatous cells known as companion cell. The sieve tube element interacts with companion cells to distribute organic compound (Fig. B.11.4).



(a) Xylem



(b) Phloem

Figure B.11.4

The Vascular Tissue (a) Xylem: Xylem vessel elements are dead, hollow tubes. The walls are strengthened with spirals of lignin showing perforation plate. The cells of tracheid and Fibre have tapering ends. (b) Phloem: Sieve tube members are joined at sieve plates.

- **Dermal tissue:** All the surface of primary plant parts are covered and protected by dermal tissue system called **epidermis**. Epidermal cells are highly variable both in terms of function and structure. In leaf the epidermal cells contain **stomata**. The stoma is an opening surrounded by two specialised kidneys shaped guard cell. The guard cell contains chloroplast. The guard cells regulate the opening and closing of stomata. The gas exchange in plants takes place through stomata. The epidermal cells are modified into **spines**, **hair** and **trichomes**. These modifications are adaptive features of the plant, and help to grow in adverse conditions. **Periderm** commonly replaces epidermis after secondary growth.

Eudicots (Dicots) and Monocots consist of same tissues, but each has some tissues organised in distinctive ways.(Fig. B.11.1)

The Tissue Systems

1. **Ground Tissue System:** It makes major portion the plant body. It is made of simple tissue. It functions primarily in storage, support, photosynthesis and the production of defensive and attractive substances (resin, tannin and anthocyanin).
2. **Vascular Tissue System:** It mainly consists of xylem and phloem. Xylem distributes water and dissolved ions in the plants and phloem transports the photosynthetic

product.

3. **Dermal Tissue System:** It covers and protects plant surfaces. All parts of young plants are covered by an epidermis which may be a single layer of cells or several layers. It is a complex tissue as it includes specialised cell types, such as guard cells that form the stomata for gas exchange in the leaves. The shoot epidermis secretes a layer of wax-covered cutin, the cuticle that helps to retard water loss from stems and leaves. The stems and roots of woody plants have a dermal tissue system called the **periderm**, a protective covering**.**

Meristems

The growth in plants occurs through the activity of meristematic cells. The meristem cells are small, completely filled with protoplast, thin walled and rectangular cells. The vacuoles are extremely small. The cytoplasm does not contain chloroplast. The cells are closely packed, with no intercellular spaces. The lengthening of shoot and root occurs as both have meristem in their apex. There are three main types of meristem, depending on their location and origin in the plant body.

1. **Apical Meristem**: The apical meristem is present at the tip of the plant. Its main function is to begin growth of new cells in the young seedling at the tips of root and shoot. The apical meristem is of two types (Fig. B.11.5):
    - **Shoot apical meristem**: The shoot apical meristem is present at the dome shaped tip of the stem. It gives rise to leaf primordial in a vegetative apex. At maturity it turns to floral apex and forms petals, sepals, stamens and a gynoecium.
    - **Root apical meristem**: The root apical meristem is sub-apical in position. It is covered by root cap. The center of root apical meristem is occupied by an inactive zone called **quiescent center**, which has low mitotic activity.

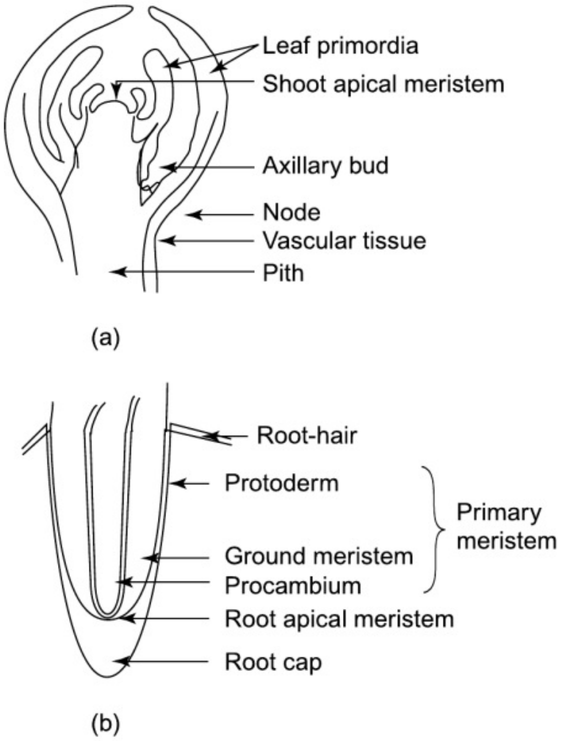


Figure B.11.5

Apical Meristems (a) The shoot meristem consists of domed shaped structure covered by young leaves (b) The root meristem consists of a zone of cell division protected by root cap

Both the apical meristem gives rise to three primary meristems, which divide and differentiate to form the tissue system in an adult plant.

Protoderm → epidermis
Ground meristem → ground tissue
Procambium → primary vascular tissues

2. **Intercalary Meristem**: It is only present in monocots. It is capable of rapid growth and re-growth. The leaf growth in grasses is due to active division in intercalary meristem. This leaf growth is an adaptive feature which allows damaged leaves to rapidly regrow. The damage by grazing animals and lawn-mowers do not kill the grasses.
3. **Lateral meristem**: Two lateral meristems in older stems and roots of woody plants produce secondary growth (increase in diameter). These are

Vascular cambium → secondary vascular tissue
Cork cambium → periderm (replaces the epidermis)

For a vegetative growing plant to flower, an apical meristem in the shoot system must become an inflorescence meristem, which in turn must give rise to one or more floral meristem.

B.11.2 SEXUAL REPRODUCTION

Sexual reproduction promotes genetic diversity in a population. The flower is an angiosperm's structure for sexual reproduction. Flowers typically have **sepals, petals,** and one or more **stamens** and **carpels** and the **receptacle**. Some flowers have **nectar**. The outermost whorl of flower is known as **calyx** (a group of sepals), it protects the interior organs of the flower. There are many kinds of calyx**;** **Perianth**, it is generally green and situated below the flower; **Glume**, is calyx of grasses, encloses one more **florets**. The **corolla** constitutes colorful petals. It also protects the interior part of the flower from heat and helps to attract **pollinator**. In some flowers nectar or appendage are attached to corolla. Flowering plants have microscopic gametophytes (Fig. B.11.6).

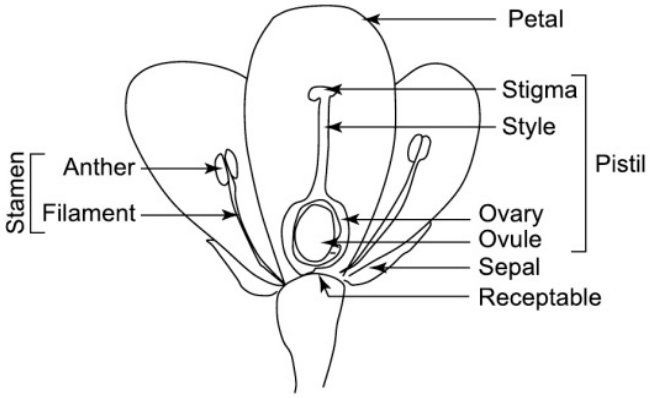


Figure B.11.6

An angiosperm flower showing male and female reproductive parts

Male Gametophyte

Inside the petals (corolla) of flowers are stamens. Nearly all stamens consist of an **anther** and a single-veined stalk (filament). An anther has **pollen sac**, which develop into male gametophyte (microgametophyte) is the **pollen grain**, which usually contains two cells.

Female Gametophyte

A flower's female reproductive parts are located at its centre, called **carpel**. The upper portion of carpel, **the stigma**, is a sticky or hairy surface that captures the pollen grain. Inside carpel ovules are formed on the inner ovary wall. Each consists of a female gametophyte. The female gametophyte (megagametophyte) is an **embryo sac**, which typically contains eight nuclei in a total of seven cells. Following **pollination**, the pollen grain delivers **sperm cells** to the embryo sac by means of a **pollen**

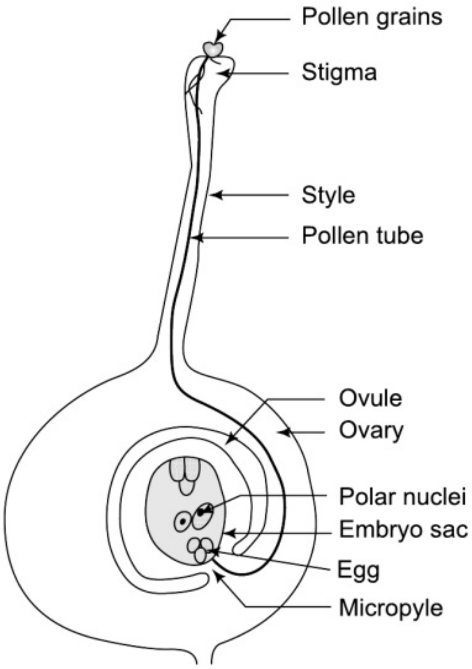


Figure B.11.7

The process of fertilisation in flowering plants. The pollen grain germinates and forms pollen tube on the stigma. The long pollen tube carries the male nucleus for fusion with egg nuclei

tube. Most angiosperms exhibit **double fertilisation**. One sperm nucleus fertilises the egg, forming a **zygote**, and the other sperm nucleus unites with the two **polar nuclei** to form a **triploid endosperm**. The zygote develops into an embryo (with an attached suspensor), which remains quiescent in the seed until conditions are right for germination. Ovules develop into seeds, and the ovary wall alongwith the enclosed seeds develop into a fruit.

Pollen allergy-*Allergic rhinitis* in every spring and summer, flowering plant release pollen grains. The pollen grains from different plants have differences in their wall proteins. Some people are allergic to these pollens. This results in a profusely running nose, reddened and itchy eyelids, congestion and sneezing. This is also called *Hay fever*.

Fruits

Fruits are classified according to whether they are *dry* or *fleshy*, derived from one or more ovaries, and incorporate other tissues beside those of the ovary.

Table B.11.1

The different types of fruits in flowering plants

Types of fruits
Simple fruits: From one ovary of one flower
Dry fruits
Dehiscent:
Fruit wall spilts to release seeds. Legume (e.g., pea, bean), poppy, larkspur, mustard
Indehiscent:
Fruit wall does not split to release seeds. Acorn, grains (e.g., corn), sunflower, carrot, maple
Fleshy fruits
Berry:
Compound ovary: many seeds, tomato, grape, banana
Ovary wall is hard: cucumber, watermelon
Hesperidium: Ovary wall is leathery, orange lemon
Drupe:
One or two flowers, thin skin, part of flesh around a usually hard seed. Peach, cherry, apricot, almond and olive
Aggregate Fruits
Many ovaries of one flower, all attached to the same receptacle, many seeds, e.g., raspberry, blackberry
Multiple Fruits
Fused ovaries of many flowers. e.g., pineapple and fig
Accessory Fruits
Most tissues of the flesh are not derived from ovary; mainly from the receptacle, e.g., Pome (apple pear), strawberry

Seeds and fruits are structurally adapted for dispersal by air currents and many kinds of animals

B.11.3 ASEXUAL REPRODUCTION

Asexual reproduction allows rapid multiplication of organisms that are well suited to their environment.

Table B.11.2

Asexual modes of reproduction in flowering plants

Mechanism	Example	Characteristics
Vegetative Reproduction on Modified Stems		
Runner	Strawberry	New plants arise at nodes along above ground, horizontal stems
Rhizome	Bermuda Grass	New plants arise at nodes of underground horizontal stems
Corm	Gladiolus	New plants arise from axillary bud on short, thick, vertical underground rhizome
Tuber	Potato	New shoots arise from axillary buds on tubers, which are the enlarged tips of slender underground rhizome
Bulb	Onion,	New bulbs arise from axillary buds
	Lily	On short underground stems.
Parthenogenesis		
	Orange, Rose	An embryo develops without nuclear or cellular fusion (e.g., from an unfertilised haploid egg or by developing adventitiously, from tissue surrounding the embryo sac)
Vegetative Propagation		
	Jade plant, African Violet	A new plant develops from tissue or structure (a leaf) that drops from the parent plant or is separated from it.
Tissue culture propagation		
	Orchid Lily, Wheat, Rice, Corn, Tulip	A new plant is induced to arise from a parent plant cell.

CHAPTER TWELVE

PLANT PHYSIOLOGICAL PROCESSES

B.12.1 PLANT NUTRITION

Every living being must obtain raw materials from its environment. The autotrophs make their own organic compounds from simple inorganic nutrients. The heterotroph organisms such as animals and fungi, require pre-formed organic compounds as food.

Modes of Nutrition in Plants

Autotrophic

Photoautotrophic: All green plants, purple, red and green bacteria.
Chemoautotrophic: Nitrifying bacteria, Iron bacteria and Sulfur bacteria.

Heterotrophic

Parasitic
  Stem parasitic*:* *Cuscuta*, *Loranthus*
  Root parasitic: *Orbanche, Santalum*
Saprophytic: *Monotrapa*, *Agaricus*, *Rhizopus*
Symbiotic: Lichen, Root nodule, Mycorrhiza
Insectivorous: *Drosera*, Utricularin, *Nepenthes*, *Dionea*

Plants are **autotrophs** that obtain carbon by photosynthesis, and minerals and water from the soil. Roots obtain most of the mineral nutrient needed for the growth from the soil. Plants require some of the minerals to complete its life cycle; these are known as **essential elements**. An essential element cannot be replaced by another element. Essential elements fall mainly into two categories: (see Table B.12.1)

- **Macronutrients**: Plants need macronutrients in concentrations of at least 1 gram per kilogram of their dry matter.
- **Micronutrients**: Plants need micronutrient in concentration of less than 100 milligrams per kilogram of their dry matter.

Before a plant, that is deficient in an essential element, dies it usually displays characteristic deficiency symptoms, such as discoloration or deformation of its leaves (Table B.12.2). It helps in the application of the fertilizers. The requirement of each element was discovered by growing plants in the solution lacking that element; the technique of growing plants in liquid is known as **Hydroponics**.

Table B.12.1

Mineral elements required by plants

Element	Absorbed form	Major function
Macronutrients		
Nitrogen (N)	NO_3^- and NH_4^+	In proteins, nucleic acids, etc.
Phosphorus (P)	H_2PO_4 and HPO_4^{2-}	In nucleic acid, ATP, phospholipids, etc.
Potassium (K)	K^+	Enzyme activation, water and ion balance, stomatal opening
Sulphur (S)	SO_4^{2-}	In proteins and coenzymes
Calcium (Ca)	Ca^{2+}	Affects the cytoskeleton, membranes and enzymes
Magnesium (Mg)	Mg^{2+}	In chlorophyll, required by enzymes, stabilises ribosomes
Micronutrients		
Iron (Fe)	Fe^{2+} and Fe^{3+}	In active site of many redox enzymes and electron carriers, chlorophyll synthesis
Chlorine (Cl)	Cl^-	Photosynthesis, ion balance
Manganese (Mn)	Mn^{2+}	Activity of many enzymes
Boron (B)	$B(OH)_3$	Possibly carbohydrate transport
Zinc (Zn)	Zn^{2+}	Enzyme activation, auxin synthesis
Copper (Cu)	Cu^{2+}	In active site of many enzymes & electron carrier
Nickel (Ni)	Ni^{2+}	Activation of one enzyme
Molybdenum (Mo)	MoO_4^{2-}	Nitrate reduction

Table B.12.2

Some Mineral Deficiencies in Plants

Deficiency	Symptoms
Calcium	Growing point dies back, young leaves are yellow and crinkly
Iron	Young leaves are white or yellow
Magnesium	Older leaves have yellow in stripes between veins
Manganese	Younger leaves are pale with green veins
Nitrogen	Oldest leaves turn yellow and die prematurely; plant is stunted
Phosphorus	Plant is dark green with purple veins and stunted
Potassium	Older leaves have dead edges
Sulphur	Young leaves are yellow to white with yellow veins
Zinc	Young leaves are abnormally small; older leaves have many dead spots

The availability of mineral nutrients to plant roots depends on the presence of clay particles in the soil. The negatively charged clay particles bind the positively charged ions of many minerals. However there is no mechanism for binding anions, the negatively charged ions. As a result, important anions such as nitrate (NO_3^-) and sulphate (SO_4^{2-}) are unavailable to the plants. There is a vast reservoir of nitrogen in the form of nitrogen gas in the atmosphere. However, plants cannot use N_2 directly as a nutrient. A few species of bacteria have an enzyme that enables them to convert nitrogen into biologically useful form by a process called **nitrogen fixation**. Some nitrogen-fixing bacteria live freely in the soil, while others live symbiotically as **bacteroids** within plant roots. In nitrogen fixation, nitrogen gas (N_2) is reduced to ammonia (NH_3) or ammonium ion (NH_4^+) in a reaction catalysed by **nitrogenase**. Nitrogenase requires anaerobic conditions, but the bacteroids in **root nodule** require oxygen, which is maintained at the proper level by ***leghemoglobin*.** The root nodule is formed by the interaction between the root system of a legume and *Rhizobium*. **Chemolithotropic** bacteria in the soil increase the availability of nitrogen and sulphur to plants.

Mycorrhizae are root-fungus associations that greatly increase a plant's absorption of water and minerals. Plants and bacteria interact in the global nitrogen cycle, which involves reduction and oxidation of nitrogen containing molecules.

Nitrification by bacteria converts ammonia to nitrate ions in the soil. **Nitrate reduction** is carried out by the plant's own enzymes, enabling plants to form their own nitrogen compounds. **Denitrification** returns nitrogen from animal wastes and dead organism to the atmosphere.

Nitrogen fixation in soil:

$$\text{(air) } N_2 \xrightarrow[\text{Nitrogenase}]{\substack{\text{Nitrogen}\\\text{Fixation}\\\text{Bacteria}}} NH_3\ NH_{4^+} \xrightarrow[\substack{\text{Nitrosomonas}\\\text{Nitrococcus}}]{\text{Nitrification}} NO_{2^-}$$

$$\xrightarrow[\text{Nitrobacter}]{} NO_{3^-} \text{ (soil)}$$

Nitrate reduction in Plants:

$$\underset{\text{(soil)}}{NO_{3^-}} \xrightarrow[\text{Chloroplast}]{\substack{\text{Nitrate}\\\text{reduction}}} \underset{\text{(plants)}}{NH_{4^+}} \xrightarrow[\substack{\text{Denitrifers}\\\text{(Bacteria)}}]{\text{Denitrification}} \underset{\text{(air)}}{N_2}$$

Carnivorous plants are autotrophs that supplement a low nitrogen supply by feeding on insects. **Parasitic plants** draw on other plants to meet their needs, which may include minerals, water, or the products of photosynthesis.

B.12.2 TRANSPORT IN PLANTS

Terrestrial plants must obtain both water and mineral nutrients from the soil, usually by way of their roots. The roots in turn obtain carbohydrates and other important materials from the shoot. **Osmotic** mechanisms govern the movement of water from the soil into vascular tissues. This is a **passive** process. However uptake of minerals from the soil occurs against an electrochemical gradient; it is an **active** process which requires energy and membrane transport proteins. Transport in plants occurs at three levels:

(i) The uptake and release of water and solutes by individual cells.
(ii) Short-distance transport of substances from cell to cell.
(iii) Long-distance transport of sap within the xylem and phloem.

The first two levels of transport takes place at the cell level, these are also referred as **cellular-level transport**. The transport at the cellular level takes place due to difference in solute concentration and water potential. Water will flow through the membrane from a solution of high water potential to a solution of low water potential. The movement of water through cells follows two routes:

- Symplastic movement: The water and solute passes through plasmodesmata (passage between two adjacent cells) from one cell to the other cell.
- Apoplastic movement: The water and solutes passes through cell walls and intercellular spaces. As the water is not passing through cytoplasm the rate of flow is more.

Xylem Transport

Xylem transport takes place against gravity, without the help of mechanical pump. It is amazing that water moves from the soil to a 100 meter tall tree. Various experimental studies ruled out xylem transport by the pumping action of living cells, and established:

- Living cells are not responsible for the upward movement of the solution.
- The movement is not caused by the roots.
- The leaves played a crucial role in transport.

The **transpiration-cohesion-tension** mechanism explains the **ascent of xylem sap**. The key elements of water transport in xylem are:

- *Transpiration*, the evaporation of water from the leaves
- *Tension* in the xylem sap resulting from transpiration
- *Cohesion* in the xylem sap from the leaves to the roots

Transpiration draws water out of leaves through stomata, resulting in tension that pulls water from the xylem. Because of cohesion between water molecules, water is pulled passively through the xylem vessels in continuous columns, always toward a region with a more negative water potential. Leaf pores called **stomata** admit the CO_2 needed for photosynthesis but also permit the exit of water by transpiration. Stomata can be opened or closed by guard cells to regulate water loss.

Transpiration a necessary evil: Transpiration from crops can be decreased, thus reducing the need for irrigation. Similarly, nurseries and gardeners would like to be able to reduce the amount of water lost by plants that are to be transplanted. A good antitranspirant can reduce the water loss from the plant. An antitranspirant is a compound that can be applied to plants to reduce water loss from the stomata without excessively limiting CO_2 uptake. ABA acts as an antitranspirant.

Phloem Transport

The products of photosynthesis, as well as some minerals, are translocated through sieve tubes in the phloem by way of living sieve tube elements. Translocation, movement of carbohydrate and other solutes in the phloem can proceed in both directions in the stem, although in a single sieve tube it goes only one way. Translocation requires a supply of ATP. Substances in the phloem are translocated from source to the sink. A **source** is an organ (such as a mature leaf or a storage root) that produces more sugars than it requires. A **sink** is an organ (such as a root, flower, developing fruit, tuber, or an immature leaf) that consumes sugar for its own growth and storage purpose.

Two steps in translocation require energy.

- Transport of sucrose and other solutes from sources into the sieve tubes, called **loading**.
- Removal of the solutes from the sieve tubes into sinks, called **unloading**.

Translocation in phloem is explained by the **pressure flow** model, according to which the difference in solute concentration between sources and sinks create a difference in positive pressure potential along the sieve tubes resulting in **bulk flow**.

B.12.3 PLANT GROWTH AND DEVELOPMENT

Growth is a process by which a plant increases in the number, size and volume of cells; involves cell division and cell enlargement. Development is the process of change from one growth stage to another; it requires cell differentiation. The increase in number and size of leaves is a growth process, while formation of flowers in an adult plant is a developmental process. The plant growth hormones, photoreceptors, genome and environment all play a role in the regulation of plant development.

Hormonal Control

Hormones (Greek, *horman* = to set in motion) are regulatory compounds that act at very low concentrations at site often distant from where they are produced. In 1937, **Went** and N. **Cholodny** gave *Cholodny-Went hypothesis*. It states that the growth curvature, as bends toward the light, is due to unequal distribution of **auxin** between the two sides of the curving organ. Auxin is responsible for cell growth and elongation. There are at least six different hormones in plants. Each plant hormone plays multiple regulatory roles affecting several different aspects of plant development.

Table B.12.3

Plant growth hormones and their role in growth and development of a plant

Hormone	Action
Abscisic acid	Inhibits shoot growth and maintains seed dormancy and winter dormancy; closes stomata
Auxin	Promotes development of buds, flowers, fruits and stem elongation, adventitious root initiation, and fruit growth; inhibits axillary bud outgrowth (apical dominance) and leaf abscission; differentiation of xylem and phloem
Brassinosteroid	Stimulates stem and pollen tube elongation; stimulates ethylene production; promotes vascular tissue differentiation
Cytokinin	Inhibits leaf senescence; promotes cell division and axillary bud outgrowth; affects root growth
Ethylene	Promotes fruit ripening and leaf abscission; inhibits stem elongation and gravitropism
Gibberellins	Promotes seed germination, stem growth and fruit development; breaks winter dormancy; Mobilises nutrient reserves in grass seeds

In plants, development is a lifelong process. Almost all differentiation in plants is irreversible, and each living plant cell possess the potential to develop into any other kind of plant cell. This phenomenon is called **cellular totipotency**. This characteristic makes plant tissue culture more feasible as compare to animal cell culture. The life cycle of a plant begins with the seeds, which need water, oxygen and the appropriate temperature for germination.

Plants do not grow at the same rate all the times. During unfavorable conditions, they limit their growth or cease to grow.

Dormancy is a special condition of arrested growth in which entire plant or such structures as seeds, buds, do not grow under unfavorable conditions. The environmental conditions such as cold exposure, dryness, a suitable photoperiod prevents tissues from breaking dormancy. Decreasing day length is the primary factor involved in the induction of dormancy in the buds. The seed of many ornamental plants have cold requirement to break the dormancy. The process of breaking dormancy by cold treatment is called **stratification**. The seeds of some desert species germinate only when sufficient rain has fallen to remove the inhibitory chemicals present in the seeds. Mechanical abrasion or breaking the seed coat to allow seed germination is known as **scarification.** Applications of gibberellins sometime break dormancy.

Seedless fruit: One method of producing seedless fruit is to treat flowers with auxin or gibberellins before their pollen mature. This triggers some species to produce fruit without fertilisation; such fruits are called **Parthenocarpic fruits** (virgin fruits). Some seedless fruits that develop in this way are apples, currants, cucumbers, tomatoes and eggplants. Seedless grapes have arisen through two gene mutations that cause formation of small underdeveloped seeds. Many varieties of citrus, oranges are due to gene mutation. Seedless bananas and water melon are triploid (they have three sets of chromosomes), resulting in abnormal egg and sperm formation and abortive seeds formation.

Photoreceptor Control

Phytochrome, a photoreceptor, is the molecule that detects transitions between light and darkness. This photoreceptor, is a bluish pigment present in the cytosol, can exist in two forms, P_r and P_{fr}. P_r absorbs red light and is thereby converted to P_{fr}. The P_{fr} absorbs far-red light and is converted to

P_r. P_{fr} is the active form of the photoreceptor; it promotes flowering in long-day plants, inhibits flowering in short-day plants, promotes germination in lettuce seeds and normal growth in seedlings. A phytochrome molecule contains two distinct parts: a light-absorbing portion (**chromophore**) and a large protein portion. The five known phytochromes mediate the effects of red, far-red and dim blue light. Phytochrome monitors light conditions in the environment and control all aspects of plant development from seed germination to flowering. The blue-light receptors are yellow pigments that absorb blue and ultraviolet light. **Cryptochrome**, which mediates the effects of high-energy light, interact with phytochrome in controlling seedling development and floral initiation. Other blue-light receptors are **phototropins**, the photoreceptors for phototropism and chloroplast movements, and **zeaxanthin**, which with the phototropins mediates the light-induced opening of stomata.

Genetic Control

Hormones and photoreceptors act through signal pathways to turn off and on the genes as the growth and development proceeds.

Environmental Control

Plant adjusts their direction and rate of growth in response to environmental stimuli (Table B.12.4). Hormones induce a difference in the rate and direction of growth on two sides of the part, which causes it to turn. When a root or shoot turns towards or away from an environmental stimulus it is called **tropism** (Greek word *trope* = turning).

Table B.12.4

The major types of plant movements or growth responses to external stimuli and interaction of growth hormones

Type of movement	Descriptions and Examples	Mechanism and other features
Tropism: Directional growth in response to an external stimulus. When a plant bends towards the stimulus, the tropism is positive; when it bends away from the stimulus, the tropism is negative.	**Phototropism**: Growth of shoot, coleoptile, or petiole of leaf towards the light	May be caused by a light-induced lateral redistribution of auxin to the shaded side of the structure. Auxin stimulates cell elongation on the shaded side.
	Gravitropism: Downward growth of roots; upward growth of shoots	Induced by gravity; vertical redistribution of auxin to the lower side of the stem & root.
	Hydrotropism: Growth of root towards region of greater water potential	Sensing cells are in the root cap. Ca^{2+} plays a major role.
	Thigmotropism: Response to contact with a solid object	Responsible for the coiling of tendrils around a support
	Heliotropism: Solar tracking	Results from turgor changes in the cells
Nastic movement: Movement in response to external stimulus	**Nyctinasty:** Sleep movements of leaf, opening and closing of petals	Results from turgor changes in the cell; under the control of biological clock and phytochrome
	Thigmonasty: Movement resulting from mechanical stimulation, such as closing of leaves of sensitive plants & venus flytrap	Results from turgor changes in the cells

Plant stresses: Stress in plants includes any factor that could lead to the death of the plant. Stress is a natural part of every ecosystem; it affects the organisms in a variety of ways. A plant's first line of defense against stress is in its roots. If the soil holding the plant is healthy and biologically diverse, the plant has a higher chance of surviving stressful conditions. The plant stress falls into two categories (Table B.12.5)

- **Abiotic stress** (physical or chemical)
- **Biotic stress** (biological)

Table B.12.5

Causes of plant stresses

Abiotic	Biotic
• Availabilty of too much or too little water	Disease causing insects
• Very high or low temperature	Disease causing microorganism.
• High or low concentration of ions (Na+, Cl^-)	Soil compaction (soil becoming hard)
• Heavy metals (Pb, Cd or Hg)	Plant-to-plant competition
• Airborne pollutants (N&S oxides)	Herbivore damage

Circadian rhythms are cycles of activity that recur at intervals of about 24 hours in an organism under constant environmental conditions. These rhythms are endogenous, caused not by environmental factors but by an internal timing mechanism, called **biological clocks**. A circadian rhythm must meet the following criteria:

- Repeat once a day.
- Repeat even if there is change in external factors.
- It should be able to adjust gradually to match the time.
- It does not change with slight change in temperature.

Plant circadian rhythm tells the plant when to flower and also controls germination, gas exchange, enzyme activity, photosynthetic activity. Light resets the biological clock; light can advance or delay the circadian rhythm.

Photoperiodism is the physiological response of organisms to the length of day or night. Many flowering plants use a photoreceptor protein, **phytochrome** or **cryptochrome**, to sense seasonal changes in night length. Photoperiodic flowering plants are classified as **long-day**, **short-day** or **day-neutral**. A long-day plant flowers when the period of light exceeds a critical length. A short-day plant flowers only when the period of light is less than critical length. Day-neutral plants flower regardless of photoperiods.

Temperature affect the flowering response. **Vernalisation** refers to the promotion of flowering in winter strains by keeping seeds at low temperature. Hormones, temperature and light interact to modify plant responses.

CHAPTER THIRTEEN

PLANT METABOLISM

The metabolism involves the processes taking place in the cells of living organisms to sustain life. These processes help organisms to grow and reproduce, maintain their structures, and respond to the environment. Metabolism involves two types of reactions:

- **Catabolism** breaks down organic matter, for example to harvest energy in cellular respiration.
- **Anabolism** uses energy to construct component of cells such as proteins and nucleic acids.

The chemical reactions of metabolism are organised into metabolic pathways. Enzymes regulate these metabolic pathways in response to changes in the cell's environment or signals from other cells.

There is similarity in the basic metabolic pathways in vastly different species. Phosphate-group transfer from ATP is central to metabolism. Autotrophic cells alone can trap energy from the environment to make ATP. All other cells are able to make ATP by pathways that release chemical energy from organic compounds (Respiration). For example, the citric acid cycle intermediates are present in all known organisms from bacteria to multicellular organisms. The respiration and photosynthesis are linked on global scale. However there are major differences in these two metabolic pathways (Table B.13.1).

Table B.13.1

Comparison of Photosynthesis and Respiration

S.No	Respiration	Photosynthesis
1.	It occurs in all living cells.	It occurs in the cells containing chlorophyll.
2.	It is a catabolic process.	It is an anabolic process.
3.	It involves breakdown of food into carbon dioxide and water using oxygen.	It involves synthesis of carbohydrates in the presence of light using carbon dioxide and water.
4.	It releases energy from sugar molecules.	It stores energy in sugar molecules.
5.	It utilises oxygen (aerobic respiration).	It releases oxygen.
6.	It produces ATP with energy released from sugars.	It produces ATP with light energy.
7.	It takes place in mitochondria.	It takes place in chloroplast.
8.	It decreases the weight.	It increases the weight.

B.13.1 PHOTOSYNTHESIS

All green plants including algae and photosynthetic bacteria are known as **phototrophs**. They capture sunlight energy to derive a metabolic process called photosynthesis ("synthesis from light"). It is the main route by which carbon and energy enter the web of life. The reaction can be written as:

$$6CO_2 + 6H_2O + \text{light energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

This reaction takes place inside the chloroplast, a double membrane organelle of eukaryotic cell.

In 1883, **T.Engelmann** illuminated *Spirogyra* a strand like green alga. Many oxygen requiring bacterial cells moved to the red and blue, where algal cells released the most oxygen, which is the by-product of their photosynthetic activity.

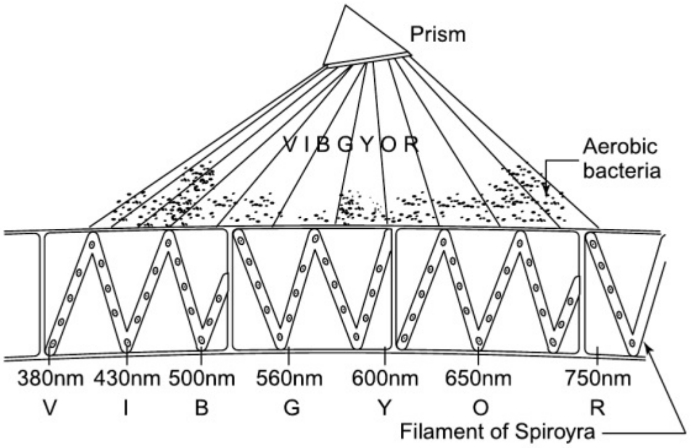


Figure B.13.1

Engelmann's experiment with filamentous green alga *Spirogyra*. The oxygen dependent bacteria accumulate near the part of alga that are illuminated with red and blue light.

Photosynthetic Organelles

In photosynthetic prokaryotes, all photosynthetic reactions take place on infoldings of the cell membranes. In plants and algae, photosynthesis takes place in organelles called **Chloroplast**. A plant cell contains 10 to100 chloroplasts. It is a double membrane structure. Within the membrane is an aqueous fluid called the **stroma**. The stroma contains the enzymes of the light independent reactions. The stroma contains stacks of **thylakoids** referred as **grana**, which are the site of photosynthesis. The thylakoids are flattened disks, bounded by a membrane with a lumen or thylakoid space within it (Fig. B.13.2).

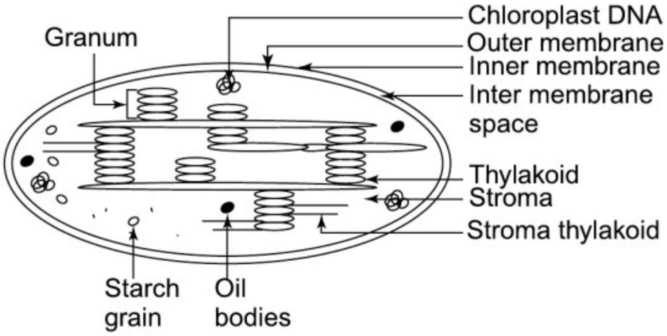


Figure B.13.2

The diagrammatic view of chloroplast

Photosynthesis involves two pathways:

- *The light reaction driven by light energy.* This pathway converts light energy into chemical energy in the form of ATP and a reduced electron carrier ($NADPH+H^+$). It takes place at thylakoids.
- *The light-independent reactions do not use light directly*, but instead use ATP, NADPH and H^+(assimilatory power made during light reaction), and CO_2 to produce sugars. It takes place in the stroma of the chloroplast. There are three different forms of light independent pathway that reduces CO_2, viz., Calvin cycle (C_3 cycle), C_4 photosynthesis and Crassulacean Acid Metabolism (CAM).

Light Reaction

The **chlorophylls**, are the main photosynthetic pigment. **Carotenoids, phycobilins** and other accessory pigments enhance their light harvesting function. Absorption of a photon puts a pigment molecule in an excited state that has more energy than its ground state. Each pigment has a characteristic **absorption spectrum**. An **action spectrum** reflects the biological activity of a photosynthetic organism for a given wavelength of light. The pigments in photosynthetic organism are arranged into antenna systems that absorb energy from light and funnel this energy to a single chlorophyll a molecule in the reaction center. Chlorophyll act as a reducing agent, transferring excited electrons to other molecules.

> **Leaf color:** The chlorophylls mask the presence of carotenoids and other accessory pigments. In autumn, however, chlorophyll synthesis lags behind and then the other pigments in the leaf show more color. Also in autumn, anthocyanins accumulate in leaf cells. These water soluble pigments appear red if fluids moving through plants are slightly acidic. Blue if the fluids are basic or colors in between if the fluids are of intermediate pH. Soil conditions contribute to the pH value. Flower petals also show color variation because of change of anthocyanin color at different pH.

This reduction leads to electron transport. This energetically "downhill" series of reduction and oxidation, are similar to electron chain of mitochondria. The final electron acceptor is $NADP^+$(nicotinamide adenine dinucleotide phosphate). Plants and algae use a two stage photosystem to carry out the light dependent reaction of photosynthesis:

- Photosystem I: Energy is transferred to a molecule of P700.
- PhotosystemII: Energy is transferred to a molecule of P680.

There are two pathways by which the electron is transported. The electron follows "Z scheme" (Fig B.13.3).

(1) **Noncyclic electron transport** uses PSI and PSII to extract electrons from water and passes them to NADPH and H^+, utilising photons absorbed by PSI and PSII and resulting in ATP synthesis. It yields NADPH, H^+, O_2 and ATP.

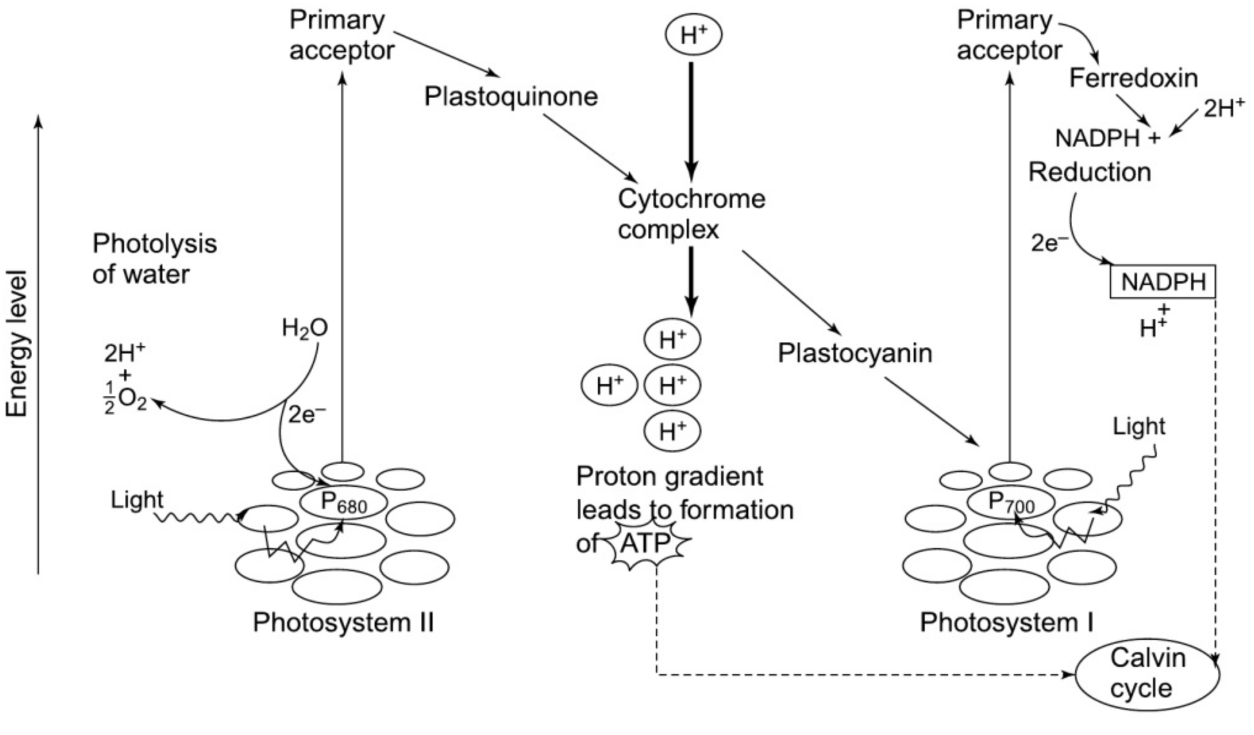

Primary acceptor
Plastoquinone
H⁺
Primary acceptor
Ferredoxin
2H⁺
NADPH +
Reduction
Cytochrome complex
Energy level
Photolysis of water
2e⁻
NADPH
H⁺
H₂O
2H⁺
+
½O₂
2e⁻
H⁺
H⁺
H⁺
H⁺
Plastocyanin
Light
Light
P680
Proton gradient leads to formation of ATP
P700
Photosystem II
Photosystem I
Calvin cycle

Figure B.13.3

Light dependent reactions: Noncyclic electron flow harvest energy that involves PSI and PSII to produce NADPH and ATP.

(2) **Cyclic electron transport** uses only PSI and produces only ATP. In this situation NADP+ does not accept the excited electrons ejected from P700 molecule. Cyclic electron flow provides eukaryotic organism with ATP when metabolic demands are such that there is no need for additional NADPH.

Dark Reaction

In 1950 **Melvin Calvin** and **Andrew Benson** traced the pathway of CO_2 fixation and formation of carbohydrate. They discovered series of compounds through which the carbon flows. This is called **Calvin cycle**, which is a three step process:

- *Fixation of CO_2*: The acceptor molecule is a 5-carbon compound ribulose 1,5-bisphosphate(RuBP). This is catalysed by the enzyme rubisco, and its product is 3PG (3-Phosphoglycerate).
- *Reduction of 3PG to form glyceraldehydes 3-phosphate (G3P)*: This series of reactions involves a phosphorylation (using the ATP made in the light reaction) and a reduction (using the NADPH made in the light reaction).

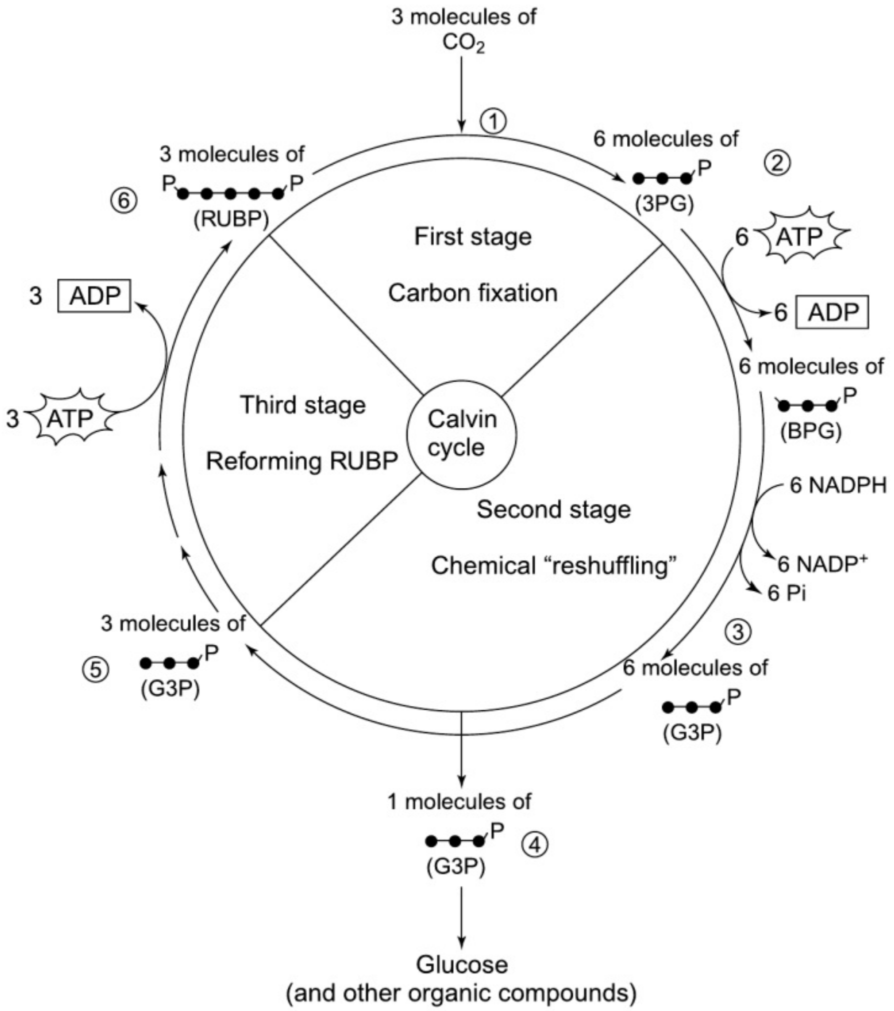

3 molecules of CO2
①
6 molecules of
P
(3PG)
②
6 ATP
6 ADP
6 molecules of
P
(BPG)
6 NADPH
6 NADP+
6 Pi
③
6 molecules of
P
(G3P)
1 molecules of
P
(G3P)
④
Glucose
(and other organic compounds)
3 molecules of
P
(G3P)
⑤
3 ATP
3 ADP
3 molecules of
P
P
(RUBP)
⑥
First stage
Carbon fixation
Second stage
Chemical "reshuffling"
Third stage
Reforming RUBP
Calvin cycle

Figure B.13.4

The Calvin cycle—For every three molecules of carbon dioxide, one molecule of three-carbon compound is produced [RuBP-1, 5-biphosphate, 3PG-3-Phosphoglycerate, BPG-1, 3-Biphosphoglycerate, G3P-Glyceraldehyde-3-phoshaphate]

- *Regeneration of the CO_2 acceptor, RuBP* Rubisco catalyses the fixation of CO_2 to RuBP, but can also fix O_2 molecule. At high temperature and low CO_2 concentration, rubisco acts as **oxygenase**, the result is photorespiration. Diversion of rubisco decreases net CO_2 fixation (Fig. B.13.4).

C_4 plants can bypass photorespiration. In plants such as corn, sugarcane and other tropical grasses, the first stable compound formed by CO_2 fixation is 4-carbon compound, oxaloacetate, and so they are called **C_4 plants**. In C_4 plants CO_2 is fixed to Phosphoenolpyryvate (PEP) in mesophyll cells. The 4-carbon product releases its CO_2 to rubisco in the interior of leaf, at bundle sheath cells. These plants use water more efficiently and require less energy than C_3 plants, because of their leaf anatomy they can trap CO_2 at low concentration.

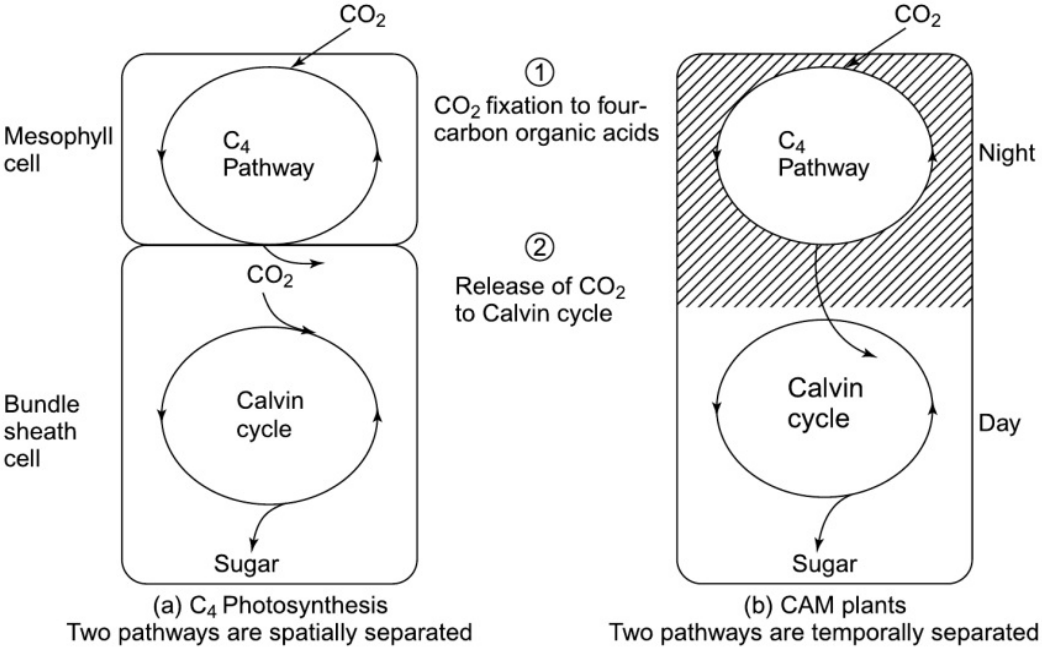
CAM (Crassulacean Acid Metabolism) plants: Xerophytes such as cacti and most succulent, also use PEP carboxylase to capture carbon dioxide. CAM plants operate much like C_4 plants, but their initial CO_2 fixation is temporally separated from Calvin cycle, rather than spatially separated as in C_4 plants (Fig. B.13.5).

- At night, when temperature is low and water loss is minimised, the stomata ae open. CO_2 is fixed in mesophyll cells and oxaloacetate is converted into malic acid.
- During the day, when the stomata close to reduce water loss, the fixed malic acid is decaroxylated to release CO_2 for operation of Calvin cycle.

C_4 and CAM plants have modified ways of fixing carbon for photosynthesis. This modification is due to stress imposed by hot and dry conditions in their environment. Photosynthesis and cellular respiration are linked through the Calvin cycle, the Citric acid cycle and Glycolysis. To survive a plant must photosynthesis more than it respires. The products of photosynthesis are utilised in glycolysis and the citric acid cycle as well as in synthesising lipids, proteins and other carbohydrates. Plants convert light into chemical energy with a photosynthetic efficiency of 3 to 6%.

Factors Affecting Photosynthesis

There are many physical and environmental factors controlling photosynthesis. Of these three



(a) C_4 Photosynthesis
Two pathways are spatially separated

(b) CAM plants
Two pathways are temporally separated

Figure B.13.5

An overall view of carbon dioxide fixation in C_4 and CAM plants.

main physical factors which affect photosynthesis are:

- *Light intensity and temperature*: At constant temperature, the rate of carbon assimilation varies with light intensity, initially increases with the increase in irradiance. However, at higher light intensity the rate of carbon assimilation does not increase further. At constant irradiance, the rate of carbon assimilation increases as the temperature is increased over a limited range. At low irradiance, increasing temperature has little effect on the rate of carbon assimilation.
- *Carbon dioxide levels and photorespiration*: RuBisCo, the enzyme responsible for capturing carbon dioxide in the light-independent reactions, has binding affinity for carbon dioxide as well as oxygen. When the carbon dioxide concentration is low, RuBisCo binds oxygen instead of carbon dioxide. This process is called **photorespiration.** This process uses energy formed during light reaction and does not produce sugars.

B.13.2 SECONDARY METABOLITES

These are organic compounds that are not directly involved in the growth and development of the plant. Absence of secondary metabolite does not result in immediate death, but has long term effect on organism survivability. It has an important role in plant defense mechanism, plant defense against herbivore and other interspecific interactions. Most of these secondary metabolites are used as medicines, flavorings and recreational drugs. Alkaloids, terpenes, phenols and glycosides are some of the common secondary metabolites (see section B of Environment Ecology, Biodiversity and Climate Change). The plants used for extraction of the secondary metabolites and their uses are given in Appendix III.

CHAPTER FOURTEEN

EVOLUTION AND SYSTEMATICS

B.14.1 EVOLUTION OF LIFE

The theory of evolution has been the greatest unifying principle in biology. Evolution takes place due to genetic change in the heritable characteristics in the successive generations. Evolution is responsible for diversity at every level of biological organisation i.e., species, individual organisms and molecules such as DNA and proteins. French biologist **Jean-Baptiste Lamarck** was the first to present a theory of evolution. He suggested that environmental pressures cause organisms to change their behavior. This changed behavior led to use or disuse of structures. Such acquired characters are passed from generation to generation. Now it is a well known fact that acquired characters are never transmitted. Hence, the view point of Lamarck was rejected.

Charles Darwin, one of the greatest biologists of his time, travelled around the world on *H.M.S.Beagle* to study plants and animals in different part of the world. In 1859, he published his work in a book titled "*On the Origin of Species by Means of Natural Selection*". The theory of evolution by natural selection, proposed by Charles Darwin and Wallace (1958), is based on the following assumptions:

(a) An organism produces more offsprings than can possibly survive.

(b) In nature, there exist variations among the organisms. The existing variation leads to differential rates of survival and reproduction.

(c) Some form of a trait is more adaptive under those environmental conditions. The organisms with such adaptive traits tend to survive and reproduce more frequently than individuals with less adaptive forms of the trait. Gradually the adaptive version becomes more common in the population.

(d) Natural selection is the difference in survival and reproduction among individuals of a population. The individuals are selected by nature. Nature selects the fittest i.e., "**Survival of the fittest".**

(e) Natural selection results in modifications of traits. It may bring about the evolution of new species.

The best example to understand Darwin's theory is that of evolution of long neck giraffes from short neck giraffes. In a population, there existed both long and short necked giraffes; however the population was dominated by short neck giraffes. During the course of evolution, due to availability of food at higher level the long necked giraffes were able to survive and reproduce. Over the period of time, the population was dominated by long neck giraffes, which evolved because they were fit in that particular environment. According to Charles Darwin, evolution occurs due to the possession of adapted traits by some individuals. The adaptive traits are those traits which an organism acquires in order to survive, due to the change in the surroundings where it resides. He understood that individuals do not evolve, but populations do evolve.

Advances in the field of genetics have helped in understanding the basic mechanism of genetic variation among different organisms of a population. A population has a defined **gene pool** (the sum of all the alleles of all the genes of all the individuals in the population). The individuals of a population generally have the same number and kind of genes. But these genes come in different allelic form, and this leads to variation in their traits. A population is evolving when some forms of a trait are becoming more or less common with respect to the other kinds, over the generation. The principal agent of change in the composition of the gene pool is natural selection. Other agents, responsible for change in the gene pool of a population, are:

- **Mutations**: Mutation provides the raw material for change, but mutation rates are usually very low. Thus mutation alone cannot determine the direction of evolution.
- **Gene flow**: It is the exchange of genes between populations and between species. It is also known as **gene migration**. Gene flow can be caused by the movement of individuals between separate populations of organisms, as might be caused by the movement of mice between inlands and coastal populations, or the movement of pollen between heavy metal tolerant and heavy metal sensitive populations of grasses. It leads to the formation of hybrid organisms. In bacteria, this is responsible for transfer of antibiotic resistance from one type of bacteria to other species. If a species of a plant grows on both the sides of a hill, pollen is likely to be transported from one side to the other and vice versa. If the pollen is able to fertilise the plant on the other side and produces viable offspring, then the alleles in the pollen are able to move from one population on one side to the other side of the hill.
- **Genetic drift**: It is one of the basic mechanisms of evolution.

  Genetic drift can also occur through a random sampling error. For instance, there are ten red petal flowers and ten white petal flowers with equal chance of surviving to reproduce. A tree fell on these small plants, killing nine white petal flowers and two red petal flowers. By chance, there is now just one white petal flower and eight red petal flowers. This population experiences genetic drift just by chance factor.
- **Non-random mating**: Some individuals have more opportunity to mate than others and thus produce more offsprings (more copies of that particular gene) than others. Random mating in population does not promote evolutionary change. By random mating the genes of a population are thoroughly mixed among the members of the next generation. Thus a population will not evolve if its members experience random mating. Nonrandom mating causes changes in the proportions of genotypes in a population.
- **Sexual reproduction**: It is the most important factor for promoting genetic variability in populations. Mechanisms that favor outbreeding further promote variability in populations.

The modern theory of evolution is a synthesis of the Darwin's theory of evolution with the principles of Mendel's genetics and mutational theory. *Evolution is the result of accumulated changes in the composition of the gene pool, which are under the pressure of natural selection.*

Evolution influences every aspect of the form and behavior of organisms. It is divided into:

- **Macro-evolution**: It occurs above the level of species, takes longer time and involves the traits of the entire species, such as **extinction** (disappearance of a species) and **speciation** (evolution of new species). Disappearance of dinosaur is a case of macro-evolution.
- **Micro-evolution:** It is the smaller evolutionary changes within a species or population. The organisms adapt rapidly to changing environment. This adaptation reduces the chances of it becoming extinct. The evolution among micro-organisms is very fast due to microevolution. The development of resistance against antibiotics in micro-organisms is a micro-evolutionary process.

Molecular Evolution

The field of molecular evolution concerns relationships between the structure of genes and proteins and the functions of organisms. The genes and proteins are compared through DNA base sequence alignment. Examination of the relative rates of similarities and differences in genes leads to the understanding of the protein function. This sequence data can be used to determine the evolutionary history of genes. Molecular evolutionary studies have provided biologists with new tools to understand the function of macro-molecules. It is used to develop synthetic molecules for industrial and pharmaceutical uses to identify and combat human diseases.

Evidence of Evolution

All species, past and present, are related to each other and have a common ancestor, starting with origin of first cells on earth. Evolutionary biologists have documented the facts of common descent. They make predictions, test hypothesis and develop theories using many of the evidences from various fields,viz.

1. **Fossil records**: Fossils are important for estimating the geological times of the development of various groups of organisms. The fossil records do not provide complete information.
2. **Comparative biochemistry and anatomy**: These evidences are based on similarities and differences in body form, functions, genetics, behavior, molecular details and biochemistry. One of the most well studied example of comparative biochemistry, is the structure of *cytochrome* (respiratory proteins). It was seen that closely related species have almost identical cytochrome whereas the distantly related have more differences. The amino acid sequence for cytochrome *c* of humans and chimpanzee is identical and differs from Rhesus monkey by only one amino acid. This indicates that all three are closely related but humans are more closely related to chimpanzee. Comparative morphology often reveals similarities that imply evolutionary relationship among groups. It includes:
    - **Homology** refers to similarity in one or more body parts between different groups of organisms. It can also be defined as the same organ in different organisms showing variety of form and function. The similarity between body parts implies that they originated from a common ancestor or evolutionary relatedness, such as the wing of a bat and the arm of a human.
    - **Analogy** refers to body parts that once differed in very distantly related organisms, but during the evolution the body parts developed similarity in structure and function as those organisms faced similar environmental pressures. If two species face a similar problem, change or opportunity, evolution may end up sharing them both in similar ways. There are some plants with needle like leaf structure. Since these plants occupy same habitat and face water scarcity, similar adaptation results in their analogous structure but they do not share common ancestory.

3. **Biogeography:** The geographical distribution of plants and animals across the world shows their relationships. This is especially obvious in the field of island biogeography. Modern biogeography includes factor affecting the distribution of organisms, and predicts its future trends. The pattern distribution of a species across geographical areas tells its evolutionary history.

Speciation

Speciation is a gradual process by which a daughter species forms from a population of the parent species. A **species** is a group of interbreeding natural populations that produces fertile offspring. A species is also reproductively isolated from other such populations. The major steps of speciation are:

1. A geographical barrier separates two populations of a species.
2. As the two populations do not interbreed the genetic differences build up in their gene pools.
3. Over the period of time the genetic differences increase and then both are considered as different species.

There are multiple ways of speciation. Broadly these are classified into three mechanisms of speciation:

(1) Allopatric speciation (Greek *allos*, "other" + patrida, "fatherland"): The members of a species are separated due to a geographical barrier, also known as geographic speciation. The isolated population then undergoes genotypic and/or phenotypic divergence as:

- They are subjected to different pressures
- These barriers prevent gene flow between the populations of the species.
- They undergo genetic drift.
- Different mutations arise in the population's gene pool.
- Over the period of time, these differences accumulates even if their individuals make contact with each other mating is prevented.
- At this stage they are to be considered members of a different species.

(2) Sympatric speciation: New species are formed from the existing species because of sudden changes in the genetic material. Sudden changes in genetic material take place due to polyploidy (the complete set of chromosome number changes) or other changes in chromosome number (addition of one or more chromosome). The original species gives rise to a new species although both are physically not separated. This is a common feature in plants; but not in animals as animal hybrids are usually sterile. A well analysed example of sympatric speciation is when insects feed on more than one species of host plants. In this case insects become specialised as they struggle to overcome the various plant's defense mechanisms.

(3) Parapatric speciation: When there is a drastic change in the environment within the parent species habitat, it gives rise to a new species while maintaining contact in adjacent habitat. The difference in sympatric speciation and parapatric speciation is that in sympatric speciation the two species are present in an overlapping habitat, while in parapatric speciation the two species are in an adjacent habitat.

Endangered Species

An endangered species is a population of organsims which is at risk of becoming extinct. The International Conservation of Nature (IUCN) has prepared a list of endangered species in Red Data Book (See Appendix V).

Extinction

It is the disappearance of an entire species. It is not an unusual event, speciation and extinction is a regular feature. The rate of extinction may vary from time to time.

The role of extinction in evolution is not well understood. In history of life there are many instances of mass extinction, during which the dinosaurs went extinct. Present day extinction rates are 100 to 1000 times greater than the past. Human activities and climate change have pivotal role in extinction of flora and fauna. Habitat degradation is currently the main cause of species extinction.

Phylogeny

A phylogeny is a description of descent of a group of organisms from their common ancestor and it is depicted in the form of phylogenetic tree. Sources of phylogenetic information include morphology, patterns of development, fossil records, and behavioral traits such as DNA and protein sequences. The phylogenetic trees are used to reconstruct the past and origin of traits; it is also used to make appropriate evolutionary comparisons among organisms and sometimes is used to predict future evolution.

B.14.2 PLANT SYSTEMATICS

Systematics is a method of understanding the evolutionary relationships of living things, trying to interpret the way in which life has diversified and changed over time. Plant systematics explores the origin and diversification of land plants. It mainly deals with the biological classification of the plants. **Theophrastus** (372–287 BC) produced *Historia Plantrum*, in which he divided over 500 medicinal plants into herbs, undershrubs and trees. The *Materia medica* of **Dioscorides** was also an important book of plant description. The most accelerating effect on the science of plant systematics was *Species Plantrum* (1753) by ***Linnaeus***. The use of **binomial nomenclature** along with a complete listing of all the plants was done. Plant systematics is closely allied to **Plant Taxonomy.** Plant systematics is involved with relationships between plants and their evolution, whereas Plant taxonomy deals actual handling of plant specimen. Plant taxonomy is the science that deals with the naming, classifying and identifying the plants.

Plant Nomenclature

Prior to the adoption of the system of naming species, there were different local names of a species. To avoid confusion in naming a species, binomial nomenclature given by *Linnaeus* was adopted. **Binomial nomenclature** is a formal system of naming species composed of two parts. The first part of the name identifies the genus to which the species belongs; the second part identifies species within the genus. A complete binomial name is always written as a latin name. The two names can be derived from their different sources. The binomial names of species are usually typeset in italics; for example *Homo sapiens*. When hand written, each part of binomial should be underlined; for example Homo sapiens. The genus name is always written with an initial capital letter and species with a small letter. The application of binomial nomenclature is now goverened by various internationally agreed codes of rules, of which the most important is International Code of Botanical Nomenclature (ICBN) for Plants.

Plant Identification

It is the determination of the identity of an unknown plant by comparison with previously collected specimens. The process of identification connects the specimen with a published name. Once a plant specimen has been identified, its name and properties are known.

Plant Classification

The classification system, particularly scientific names, can be traced back to Carolus Linnaeus during the 18th century. The number of species, known to exist by the time of Linnaeus, was too great to be familiar with even half of them. Linnaeus gave an efficient system of classification and nomenclature. Every species had both a genus name and a species name, the basis of present binomial system of nomenclature. In 1753, Linnaeus published *Species Plantarum*, in which all the plant species known at that time were included. With the discovery of evolution by natural selection, the basis of naming plants changed. The taxonomist adopted the goals of (1) developing a natural system of classification, a system in which closely related organisms are classified together, and (2) assigning plant names on the basis of evolutionary relationships. In this system, closely related species are placed into a genus; closely related genera are grouped together into a family and so on. The levels above family are order, class, division, and kingdom.

Domain Eukarya

Kingdom Fungi

Most fungi are multicellular or rarely unicellular (yeast), in which the nuclei occur in a basically continuous **mycelium**; this mycelium becomes septate in certain groups and at certain stages of the life cycle. Fungi are heterotrophic; they have cell walls, therefore, must obtain their nutrition by absorption. Most fungi are saprophytic, live on dead and decaying matter. Some are parasites, live on living organisms. Certain human diseases and conditions such as **athlete's foot** and **ring worm** are caused by fungi, as are plant diseases such as **potato blight**. Members of all but one phylum (Chytiridiomycota) form important symbiotic relationships with the roots of plants, called **mycorrhizae**. Reproductive cycles typically include both sexual and asexual phases. There are over 100,000 species of fungi. The kingdom Fungi is divided into two division—Myxomycota and Eumycota.

Kingdom Protista

Eukaryotic unicellular or multicellular organisms—their mode of nutrition includes ingestion, photosynthesis and absorption. The photosynthetic protists (the algae) have twelve phyllum.

Kingdom Plantae

The plants are autotrophic (some are derived heterotrophs), multicellular organisms possessing advanced tissue differentiation. All plants have an alternation of generations, in which the diploid phase (sporophyte) includes an embryo and the haploid phase (gametophyte) produces gametes by mitosis. Their photosynthetic pigments and food reserves are similar to those of the green algae. Plants are primarily terrestrial.

Hepatophyta: *Liverworts*—These are small plants living in moist habitats. The gametophytes are thallose or leafy, and the rhizoids are single-celled. Liverworts lack specialised conducting tissues (with possibly a few exceptions) and stomata. Hepatophyta and the two following phyla, all of which constitute the bryophytes, have multicellular gametangia with a sterile jacket layer; their sperm are biflagellated. In all three phyla, most photosynthesis is carried out in the gametophyte, upon which the sporophyte is dependent. They are the simplest of all living plants. There are about 9000 species.

Anthocerophyta: *Hornworts*—Bryophytes with thallose gametophytes; the sporophyte grows from a basal intercalary meristem for as long as conditions are favourable. Stomata are present on the sporophyte; there is no specialised conducting tissue. There are about 100 species.

Bryophyta: *Mosses*—Bryophytes with leafy gametophytes; the sporophytes have complex patterns of dehiscence. Specialised conducting tissue is present in both gametophytes and sporophytes of some species. Rhizoids are multicellular. Stomata are present on the sporophytes. There are about 9500 species.

Psilophyta: *Psilotophytes* (Whiskferns)—The Psilotophyta and the three following phyla constitute the living phyla of seedless vascular plants. Psilotophytes are homosporous. There are two genera, one of which has leaflike appendages on the stem; both genera have extremely simple sporophytes, with no differentiation between roots and shoot. The sperm are motile. There are several species.

Lycophyta: *Lycophytes*—Homosporous and heterosporous vascular plants characterised by the presence of microphylls. The lycophytes are extremely diverse in appearance. All have motile sperm. There are 10 to 15 genera, with about 1000 living species.

Sphenophyta: *Horsetail, scouring rushes*. A single genus of homosporous vascular plants, *Equisetum*, with jointed stems marked by conspicuous nodes and elevated siliceous ribs. Sporangia are borne in a strobilus at the apex of the stem. Leaves are scalelike. Sperm are motile. There are 20 living species of horsetails.

Pteridophyta: *Ferns* Mostly homosporous, although some are heterosporous; stems mostly creeping; all posses a megaphyll. The gametophyte is more or less free-living and usually photosynthetic. Multicellular gametangia and free swimming sperm are present. There are about 12000 species.

Cycadophyta: *Cycads*—Gymnosperm with sluggish cambial growth and pinnately compound, palm like, or fern like leaves; ovules and seeds are exposed. The sperm are flagellated and motile but are carried to the vicinity of the ovule in a pollen tube. There are 11 genera with about 140 species.

Ginkgophyta: *Ginkgo, maiden hair tree*—Gymnosperm with considerable cambial growth and fan-shaped leaves with open dichotomous venation; ovules and seeds exposed; seed coats fleshy. Sperm are carried to the vicinity of the ovule in a pollen tube but are flagellated and motile. There is only one species left from a once-large group.

Coniferophyta: *Conifers*—Gymnosperms (plants having naked seeds) with active cambial growth and simple leaves; ovules and seeds exposed; sperm non-flagellated. The most familiar group of the gymnosperms. There are some 50 genera with 550 species.

Gnetophyta: *Gnetophytes (cone-bearing desert plants)*—Gymnosperms with many angiosperm like features, such as vessels; the gnetophytes are the only gymnosperms in which vessels occur. They are the group of gymnosperms most closely related to angiosperms. Motile sperm are absent. There are three very distinctive genera with about 70 species.

Anthophyta: *Flowering plants; angiosperms*—Seed plants in which ovules are enclosed in a carpel and seeds are borne within fruits. The angiosperms are extremely diverse vegetatively but are characterised by the flower, which is basically insect-pollinated. Other modes of pollination, such as wind pollination, have been derived in a number of different lines. The gametophytes are much reduced, with the female gametophyte often consisting of only seven cells at maturity. Double fertilisation involving the two sperms of the mature microgametophyte gives rise to the zygote (sperm and egg) and to the primary endosperm nucleus (sperm and polar nuclei); the former becomes the embryo and the latter becomes a special nutritive tissue called the endosperm. There are about 235,000 species.

Together the monocots and eudicots represent about 97% of angiosperms. The remaining 3 per cent of living angiosperms are the magnoliids, those angiosperms with the most primitive features and the ancestors of both monocots and eudicots.

CHAPTER FIFTEEN

PLANTS AND HUMAN

B.15.1 HISTORY OF CULTIVATION

Agriculture began about 11,000 years ago in the fertile crescent of the old world. The Fertile Crescent extends from Lebanon and Syria through Iraq to Iran. The plants such as barley, lentils, wheat and peas were grown. While cultivating, the early farmers selected the plants which were more nutritious and easier to harvest. Agriculture spread from this centre across Europe, reaching Britain by about 6000 years ago. Many crops were first brought into domestication in Africa, including yams, okra, coffee and cotton. In Asia, crops such as rice, soybean, citrus, mangoes and bananas were developed.

Agriculture was developed independently in the new world utilising many new species. Many crops from the new world were brought into cultivation in the old world starting from Europe. These included maize, kidney beans, tomatoes, tobacco, chilli peppers, potatoes, sweet potatoes, pumpkins, squashes, avocado, cacao and cotton. The world's food supply is mainly based on a relatively small number of the crops. Wheat, maize and rice provide the most of the calories we consume.

Cereals and Millets

Cereals (ceres-goddess of grain) are the most important source of food. Cereals belong to family Poaceae. They contain carbohydrates, proteins, fats, minerals and vitamins. The cereals having characteristics—one seeded, dry indehiscent grain, which can be stored for longer time and can be easily transported. Cereals are the first one to be cultivated and provided the basis for civilisation. Besides cereals and millets there are few others unrelated plants, such as buckwheat (*Fagopyrum esculentum)* and amaranthus, are used as cereals. They are called as '**pseudocereals**'. The most cultivated species are: Wheat, Maize, Rice, Rye, Oats, Sorghum and Barley.

Wheat

Botanical name: *Triticum aestivum* Family: Poaceae

Wheat is consumed at every meal in some or the other form. The grain is ground into flour which is used for making roti. The flour contains gluten, a protein which gives elasticity to the flour. Refined wheat flour (maida) is used for making bread, cakes, biscuits and other bakery products. Coarsely grounded wheat (semolina or sooji) is used for making sweets, halwa and upma. Wheat porridge (Dalia) is also made from hard grains. The tetraploid wheat such as *Triticum durum* is used for making macroni, spaghettii, vermicelli, noodles, etc. There have been many landmarks in the breeding of wheat. One of the greatest developments in modern times is the development of dwarf varieties of wheat at the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico. **Dr. Norman E. Borlaug** was awarded the noble peace prize (1970) for development of new varieties which support higher yield of grain without collapsing of the stem. This **"green revolution"** reduced the danger of famine. In India, the wheat crop is affected by different rust diseases caused by a basidomycetes, *Puccinia graminis*, and other related species. At the Indian Agriculture Research Institute (IARI) in New Delhi, New Pusa or N.P. varieties have been developed by **Dr. B.P. Pal**, which is resistant to all three wheat rusts. **Dr. M.S. Swaminathan** is recognised as the **father of the green revolution in India**.

Maize

Botanical Name: *Zea mays* Family: Poaceae

Maize ranks second in the order of world grain production. It is *America's greatest gift to mankind.* Ears of maize or corn differ greatly from those of its ancestor. Maize is a domesticated form of a large wild grass, teosinte. Teosinte has hundreds of small, narrow, two rowed ears. The ear is woody and grains cannot be separated from the ear. As a result of human selection for these characteristics, maize differs from teosinte. *Maize is known only as a cultivated plant and can not survive on its own in the wild.* The grains are enclosed in an overlapping leaf sheath that does not allow dissemination of the grain. Originally mainly used to feed people, maize is now one of world's chief foods for domestic animals. In the United States, some 80% crop is consumed by animals. There are five main types known; popcorn, flint corns, flour corns, dent corns and sweet corn. Dent corn has dent in the grain and mainly grown used as animal food. Dent corn is increasingly important as a source of high-fructose corn syrup, as used in canned soft drinks, and of ethanol.

Rice

Botanical name: *Oryza sativa* Family: poaceae

Rice provides half of the food consumed by more than 1.6 billion people and more than quarter of the food consumed by rest of the people. It is grown on about 11% of the world's cultivated land. When rice is grown in stagnant water, fish are often farmed in the flooded fields and harvested along with the rice. In 1962, *An International Rice Research Institute* (IRRI) in the Philippines was established.

The methods of breeding rice are similar to those used in breeding wheat and other self-pollinated crops. The objectives of these programs are:

- Germ plasmas collection to introduce new varieties.
- Selection of superior genotypes for optimum benefit.
- Hybridisation to produce new varieties with suitable characteristics.

Rice paper is not made from rice, but from the pith of *Tetrapanax papyriferrum* a tree from Taiwan belonging to family Araliaceae.

In India about half of the rice is **parboiled**. The paddy is steeped in cold or hot water for varying period up to 3 days. It is then steamed at low pressure and dried. The hull is then removed by **milling**. Parboiling results in less breakage of the grain during milling. The important nutrients are also retained in the grain and the grain can be stored for longer time. The different processing methods are used to get Parched rice; rice flakes and puffed or popped rice.

In addition barley, oats and rye are the other true cereals. Some small-grained members of the grass family are also edible. These are called **millets**. Besides being used as food, these plants are of importance for industrial purposes and as fodder for livestock.

Pulses

The legumes or pulses are a rich source of proteins. They also have high carbohydrate and fat content.

The seeds have low water content and can be stored and transported easily. The legumes grow rapidly and enrich the soil by fixing atmospheric nitrogen. Thus they are very good for soil enrichment.

India is the largest producer of pulses. Chick pea and pigeon pea are two important pulse crop constituting 55% of the total pulses. India is the largest producer of groundnut (*Arachis hypogea)* and mainly used for extracting an edible oil from the seeds. The seeds have high calorific value. Soybean (*Glycine max*) is one of the most valuable legumes because of the high protein and oil content.

Legumes: The nitrogen fixers

The bacteria (*Rhizobium* species) live freely in the soil but do not fix atmospheric nitrogen. However, when these bacteria live symbiotically inside the root nodule (special tubercle like, structure containing bacteria), they fix atmospheric nitrogen by converting it into nitrates and other compounds which can be used by plants. The nodules contain a special red pigment called leghaemoglobin is very important for nitrogen fixation. This process of nitrogen fixation adds nitrogen to soil making it available for biological circulation (see section B.12.1).

Fruits and Nuts

A fruit (Latin, *Frui* = to enjoy) is a product of growth which takes place after the act of fertilisation. Most fruits are consumed fresh as desert. Majority of fruits do not have a long shelf life. Many fruits are preserved in different ways and enjoyed for their taste and flavor. The fruits are a rich source of vitamins and minerals. They also contain antioxidants.

Nut is the dry edible seeds or fruits which grow in a woody shell. The nuts are rich in protein and fat. They are a good source of vitamin and minerals and provide sufficient energy for activating the body. They are an instant source of energy.

Vegetables

Vegetables are defined as one of the many nutritious foods obtained from plants or plant part. They may be eaten as raw or cooked. They are a rich source of vitamins, especially niacin, riboflavin, thiamin and vitamin E. It provides the roughage necessary for proper functioning of alimentary canal. Most vegetables contain large amounts of moisture and fewer calories.

Spices and Herbs

Spices and herbs have been used to flavor food. Spices are strongly flavored parts of plants that are rich in essential oils and are derived from the roots, bark, seed, fruits or buds. Herbs are usually the leaves of non-woody plants. Both integrate completely and are used by human to flavor food. The search for spices played a major role in the great Portuguese, Dutch and English voyages and for a great deal of warfare as well. Black Pepper (*Piper nigrum*), **King of spices**, has been known for thousands of years as an important spice. The use and consumption of black pepper is approximately equal to that of all other spices combined. Nutmeg (*Mrystica fragrans)* is one of the most important spices from tropical Asia.(Appendix III)

Oil Crops

Vegetable fats and oils, also called fixed oils, are triglycerides of organic fatty acids. Fats are solid or semi-solid at room temperature. The vegetable oil is extracted from plant material by hydraulic or screw presses or solvent extraction systems. Ground nut and mustard are the most common edible oil crops.

Oil palm (*Elaeis guineensis*) is native to West Africa, but is now grown in tropical regions. It is among the most important cash crop of today.

Sugar and Starches

Sugarcane (*Saccharum officinale*): It was domesticated in New Guinea. It is the most important industrial crop of tropical and subtropical regions. The main product of sugarcane is sucrose. Sucrose is extracted and purified in factories and used as raw material for production of refined sugar. Its other products include falernum, molasses, rum, bagasse and ethanol.

Sugar beet (*Beta vulgaris*): The sugar beet is a variety of the ordinary beet; it is developed by selection of fodder crop and now used as root crop. The sucrose content of the root is more than 20%.

Potatoes (*Solanum tuberosum*): Potato is the gift of the new world. This is called the **Irish** potato because in 1845–46, the worst famine in Ireland and many other parts in Europe occurred because of the failure of potato crop due *Phytophthora* infection. Green potatoes contain a poisonous glycoside, solanin, which in high concentration may cause sickness and even death in both humans and livestock. The potato is stem tuber used in many ways. Vodka a Russian alcoholic beverage is prepared by the fermentation of cooked potatoes.

Coconut (*Cocos nucifera*): The vast range of coconut may be the result of natural dispersal of the fruits floating in the sea rather than human intervention. Each tree produces about 50 to 100 fruits (drupes) each year, and they are a rich source of proteins, oils and carbohydrates. Coconut shells, leaves, husk fibres and trunks are used to make many useful items, including clothing, buildings and utensils; it is the solid and liquid endosperm that we eat.

Beverages

It can be grouped into two types: alcoholic and non-alcoholic. Non-alcoholic drinks are stimulants because they contain caffeine and its relatives.

Coffee (*Coffea arabica*) and **Tea** (*Camellia sinensis*): Both are the two most important beverages in the world. Both are consumed primarily because of the stimulating alkaloid, caffeine present in them. Coffee is made from dried, roasted and grounded seeds, whereas tea is prepared from dried leaves. Coffee seeds are processed by either dry or wet method. The processing of tea leaves depends on the final type of tea. The leaves are fermented to bring about alteration of various chemical constituents of leaf. Green tea is unfermented, whereas the Oolong tea is semi-fermented.

Cacao (*Theobroma cacao*) is the source of chocolate and cocoa. The fruit contain several large seeds or "beans". Cacao was first domesticated in Mexico, where chocolate was a prized drink among the Aztecs. The beans were used as currency.

Medicinal Plants

Many herbs and spices used in Indian cooking are known to have medicinal properties. Besides, many medicinal plants are routinely used by the practitioners of Ayurveda. Some of the most important medicinal plants, their constituents and medicinal properties are given in Appendix III.

Fumitory and Mascatory

Tobacco: It is obtained from the fresh leaves of *Nicotiana tabacum* and *N.rustica*. The leaves are harvested and cured to allow for the slow oxidation and degradation of carotenoids in the tobacco leaf. Before packing, the tobacco is often combined with other additives.

Cannabis: Cannabis smoking involves inhaling vapors released by heating the flowers and subtending leaves of the *Cannabis* plants, known as *marijuana*. Alternatively, the cannabis flowers may be sifted producing *kief,* a powder rich in the oil-glands or trichomes which contain highest amount of cannabinoids. It is consumed to produce a feeling of relaxation, medically to relieve stress or suppress nausea.

Opium: Opium is the dried latex obtained from the opium poppy—*Papaver somniferum*. Opium contains up to 12% morphine, an alkaloid, which is frequently used to produce heroin. The latex also includes codeine and non-narcotic alkaloids such as papverine, thebaine and noscapine.

Rubber

Natural Rubber is collected from the latex yielding trees *Hevea* and *Castilla.* "Caoutchouc", the world first used to describe the condensed juice of the *Hevea* tree, meaning weeping tree. The commercial source of natural rubber is the para rubber tree (*Hevea brasiliensis*) a member of family Euphorbiaceae. Other plants are *Palaquium gutta* (gutta-percha), *Ficus elastica*, *Euphorbia*, *Parthenium argentatum* (guayule) Natural rubber is vulcanised. Vulcanisation is a process by which the rubber is heated and sulphur, peroxide or bisphenol are added to improve resistance and elasticity. Carbon black is added to rubber to improve its strength. Latex is a polydispersed colloidal system of rubber particles in an aqueous phase. The rubber produced from latex contains besides the hydrocarbons, relatively small quantities of proteins, carbohydrates, resin-like substances, mineral salts and fatty acids. Latex coagulates within few hours of tapping, thus while collecting the latex ammonia is added. The standard method of tapping involves cutting the bark of tree. The cut is generally slant down from right to the bottom left of the trunk at an angle of about 35°.

Fibre Crops

Cotton: Cotton fibre is soft, fluffy and pure cellulosic in nature. The fibres grow in a **boll** around the seeds of the genus *Gossypium.* It belongs to Malvacae family. There are four commercially grown species of cotton. Genetically modified cotton was developed to reduce the use of pesticides. The gene coding for Bt toxin has been inserted into cotton, causing cotton to produce natural insecticide in the tissues. Bt cotton is ineffective against many cotton pests. Cotton fibre is formed from the epidermal layer of the seed. The fibre is separated from the seed by ginning. The fibre is used to make a number of textile products. The cotton seed which remains after the ginning is used to produce cotton seed oil.

Jute: Jute fibre is produced from *Corchorus* species, which belongs to family Tiliaceae. Jute is a ligno-cellulosic fibre that is obtained from the stem of the plant. Jute fibre is 100% bio-degradable and the cheapest vegetable fibre. It is a natural fibre with golden and silky shine and hence called ***The Golden Fibre***. The fibre is extracted by the process retting. Retting is the process of extracting fibre from stem (bast fibre). There are two ways of retting; mechanical (hammering) and chemical retting (boiling and applying chemicals). In mechanical retting method, after harvesting the jute stalks are tied into bundles and submerged in water for about 20 days. During this time bacteria act on the stem and separate the fibre by dissolving pectin present in the plant tissues. When the jute stalk is well retted, the stalks are hit with hammer to extract the fibre.

B.15.2 PLANT DISEASES

The scientific study of plant diseases caused by pathogens and environment conditions is known as **Plant Pathology** (Phytopathology). Plant pathology also involves the study of pathogen infection, disease cycles, plant disease resistance and management of plant diseases. The effect of pathogen on humans and animals is also a part of this field.

Bacterial Diseases

Some of the most destructive diseases of plants are caused by bacteria, such as **blights**, **soft rots** and **wilts**. Blights are characterised by rapidly developing **necrosis** on stem, leaves and flowers. Bacterial soft rots occur most commonly in the fleshy storage tissues of vegetables, such as carrots or potatoes. Bacterial vascular wilts affect mainly herbaceous plants. The bacteria invade the vessels of xylem, where they multiply. The bacteria commonly degrade portions of the vessel walls and even cause the vessel to rupture.

Viral Diseases

Over 2000 kinds of plant diseases are caused by more than 600 kinds of viruses diseases. The major symptoms produced by virus infection is reduced growth, resulting in various degree of dwarfism and stunting of the plants. The symptoms appear on leaves, where the virus interferes with chlorophyll production, thus affecting photosynthesis. **Mosaics** and **ring spots** are the most common symptoms. In mosaic diseases, light green, yellow or white areas appear intermingled with the normal green of leaves and fruits. In ring spot diseases, **chlorotic** (yellow) or **necrotic** (dead tissue) rings appear on the leaves. Less common viral diseases include leaf roll, canker and tumor.

Fungal Diseases

The members of Ascomycetes and Basidomycetes cause majority of plant diseases. The fungal pathogens colonise living plant tissue and obtain nutrients from living host cells. They produce spores, which spreads long distances by air or water. Fungal diseases are controlled by fungicides.

B.15.3 CROPS IMPROVEMENT

The human population is growing very rapidly. As a result of this growth and of widespread poverty, the tropics are being destructed ecologically. There is an urgent need to increase the productivity and improvement of crop plants. Crop improvement or plant breeding is an applied branch of botany that deals with the improvement of crops and production of new varieties which are superior to existing varieties in all characters. The main aims and objectives of crop improvement are as following:

(i) It aims to improve economically useful characters in crop plants.
(ii) To incorporate as many as desirable characters as possible into a single variety.
(iii) To increase the yield of various types of plant products such as grains, pulses, fibre, oil, etc.
(iv) To develop varieties resistant to diseases, insects, drought, floods, alkaline and saline conditions.
(v) To produce early mature crops for crop rotation purpose.
(vi) Suitability of crops for easy harvesting, adaptability to wide regions.

The world food supply can be improved by

- Traditional methods of plant breeding and selection: There are five different methods of traditional plant breeding.
  (i) Plant introduction: It is introducing plants into new regions.
  (ii) Selection: This is the oldest method used for cross-pollinated crops. The farmer selects the best appearing plants in the field; collects the seeds from those plants to grow the next generation.

Table B.15.1

Plant diseases caused by bacteria, viruses and fungi

Organism	Common name of the disease	Scientific name	Affects
Virus	Bunchy top	Banana Bunchy top virus	Bananas
	Mosaic	Cauliflower mosaic virus	Mustard
Bacteria	Citrus canker	*Xanthomonas axonopodis*	Citrus
	Leaf spot	*Xanthomonas campestris*	Mustard
	Soft Rot	*Pseudomonas*	Sugarcane
Fungi	Fusarium head blight	*Fusarium* species	Wheat barley
	Rust	*Puccinia*	Cereals
	White rust	*Albugo* species	Mustard
	Blight	*Phytophthora*	Potato
	Downy mildew	*Pernospora*	Mustard

(iii) Hybridisation: It involves cross between genetically unrelated parents. The aim is to incorporate as many desirable characters as possible into one variety.
(iv) Mutation breeding: Seeds, seedlings, buds and flowers are subjected to irradiations to induce mutations.
(v) Polyploidy breeding: Utilising polyploidy for breeding

- Biotechnology and Genetic engineering.

Genetic diversity is necessary to allow crops to be modified to meet the different requirements of growing successfully in different region. However the modern commercial agriculture practices, **monoculture**, reduces genetic diversity. Among the more promising of recently developed new crops are such food plants as triticale and the grain amaranthus and various salt tolerant species. **Jojoba**, is valuable as a source of liquid wax for lubrication; **Guayule** is a source of rubber. Sunflower can be used for extraction of oil. Safflower, Yams, Tomatillo and many more are plants for future.

B.15.4 PLANTS: A BOOMING INDUSTRY

Plants teach us to be respectful of nature. There has been a rise in ethical consumerism. Organic and bio-safe, bio-degradeable such certification products are preferred by the consumer. People are becoming ecologically conscious. Anything herbal can be sold in the market. No other business is so interesting, healthy and offers such profit potential for a small investment. The present day plant industry is a dynamic, global and fast growing industry.

Floriculture

It is branch of horticulture which deals with the cultivation of flowering and ornamental plants for garden and floral industry. The types of plants cultivated are bedding plants, flowering plants, foliage plants or house plants, cut cultivated greens and cut flowers. Mostly the plants included in Floriculture are herbaceous, whereas nurseries have saplings of all types of plants. The major flowering plants are *poinsettias*, *orchids*, *chrysanthemums*. Cut flowers production is known as **cut flower industry**. **Horticulture** including floriculture is growing at galloping speed and has created ample opportunities for economic growth, considering its growth it is now termed as **"Golden revolution**".

Mushroom Culture

Mushrooms are fleshy Fungi; they first appear as white tiny balls consisting of a short stem and a cap, which later opens like an umbrella. They are a good source of high quality proteins and rich in vitamins and minerals. Mushrooms contain good amount of Vitamin C and B complex, potassium, phosphorus and sodium.

They also have medicinal properties. Mushrooms have high amount of **retene** that has antagonistic effect on some forms of tumor. Mushrooms are capable of agro-waste degradation. It is grown on organic substances either raw or composted. They are mostly waste materials from farms, plantations or factories. Therefore they help to reduce pollution. They have a huge export potential. They can be grown independent of sunlight without fertile land. Mushrooms like fruits and vegetables are perishable and require a great deal of attention during storage, marketing and processing at the post harvest stage. Discoloration, weight and flavor loss are some of the major constraints.

The following methods are used to increase their shelf life:

(i) Vacuum cooling
(ii) Keeping in a controlled atmosphere consisting of 9% oxygen and 25% percent carbon dioxide
(iii) Giving gamma radiation and storing at 15°C
(iv) Freeze drying in a solution of brine, citric acid and ascorbic acid and dehydration
(v) Canning

Hydroponics

It is technique for growing plants in nutrient solution (water with nutrients) with or without the use of an artificial medium (sand, gravel, peat-moss, coir or saw dust) to provide mechanical support. This technique can be used for commercial crop production. It is an effective way to study the nutrients requirements of the plants.

Packaging of Fruits and Vegetables

Most of the vegetables and fruits are available globally. There is big market to pack fruits and vegetables for transportation. One of the main hurdles is to increase the **shelf life** of these plant products. Shelf life is the length of time that food, drink, medicine, chemicals and many other perishable items are suitable for sale. Shelf life is different from the date of expiry, the former relates to food quality while the latter to food safety. A product that has passed its shelf life might still be safe, but quality is no longer guaranteed. In most food stores, shelf life is maximised by using stock rotation and if it is not sold such products would have to be marked as wasted, leading to a loss of profit. Shelf life is most influenced by several factors such as: exposure to light and heat, transmission of gases (including humidity), mechanical stress and contamination by microorganisms. The expiry date of pharmaceuticals specifies the date which the manufacturer guarantees the full potency and safety of a drug.

Shelf life has many attributes: bacterial control, color stability, yeast and mold inhibition, flavor stability, textural stability and aroma stability. Lowering moisture and increasing solute (e.g., sugar) increases osmotic pressure on the bacteria, causing them to burst. Adding sugar was the traditional way to control water activity to prevent bacterial growth but market value of sugar containing product is low. Preservatives and antioxidants may be incorporated into some food and drug products to extend their shelf life. Some companies use induction sealing and vacuum/oxygen-barrier pouches to assist in the extension of the shelf life of their products where oxygen causes the loss.

Parallel names used in this field of packaging are:

- **Best before:** The date indicates that the product is no longer safe to consume after the specified date. Food kept past the best before date will not necessarily be harmful, but may begin to lose its optimum flavor and texture.
- **Use By:** The food should not be eaten after the specified date. This because such foods usually go bad quickly and may be injurious to health if spoiled.

Tea and Coffee Industry

Although it is not a new field, but many new flavors, aromas and adjuvant have made tea and coffee industry a booming business.

Tea is classified into three basic types:

- **Green tea** does not undergo the oxidation process. It has herbaceous flavor and is green or yellowish in color. The leaves are sometimes steamed after which it is rolled, fired and sorted.
- **Black tea** is fully oxidised and often yields a full-bodied amber brew. It undergoes five basic manufacturing stages: withering, rolling, fermenting, firing and sorting.
- **Oolong tea** is partially oxidised and prepared by withering, rolling, fermenting and then drying. The oxidation process continues for a predetermined time based on the master's skill and knowledge.

Black tea is a variety of tea that is more oxidised than oolong, green and white varieties. Green tea loses its flavor within a year, black tea retains for several years. Black tea, without sweetners or additives, contains negligible quantities of calories, protein, sodium and fat.

Genetically Modified Foods

GM foods or GMO foods are derived from genetically modified organisms (GMOs). Genetically modified organisms have their DNA modified by genetic engineering techniques. GM foods were first put on the market in the early 1990s. The first commercial grown genetically modified crop was tomato, called **FlavrSavr**, which was modified to ripen without softening by Calgene (Monsanto based company). Currently there is a number of food species in which a genetically modified version exists.viz, soybeans, corn, cotton, alfalfa, Hawaiian papaya, tomatoes, canola, sugarcane, sugar beet, rice, sweet peppers. In recent years, many companies claim that GM crops have brought higher yields and profitability to many farmers. While their practicality or efficacies in commercial production has yet to be fully tested, the next decade may see an increase in GM products.

Organic Farming

Organic farming relies on techniques such as crop rotation, green manure, compost and biological pest control to maintain soil productivity and control pests on a farm. It strictly limits the use of synthetic fertilisers, pesticides, plant growth regulators, livestock antibiotics, food additives, and genetically modified organisms. These agricultural methods are internationally regulated by the International Federation of Organic Agriculture Movements (IFOAM). Organic farming methods include soil management, weed management, biological pest control, genetic modification and composting. The products of organic farming are free from pesticide.

Jute Industry

The Ganges delta contributes more than 80% of the jute production in the world. The jute industry has been expanding really fast spanning from a wide range of life style consumer products. Innovative ways of bleaching, dyeing and finishing processes—the jute industry now provides finished jute products that are softer, have lustre and also an aesthetic appeal. Jute has been defined as an eco-friendly natural fibre with low value textiles to high value carpets, apparel, decorative, upholstery furnishing, etc. Advantages of jute include good insulation, low thermal conductivity and a moderate moisture region. It also has acoustic insulating properties with no skin irritations. It can be blended with other fibres to produce fabrics at a reduced cost.

Chocolate

Chocolate is produced from the seeds of the tropical tree, *Theobroma cacao*. The seeds of the cacao tree have an intense bitter taste and must be fermented to develop the flavor. After the fermentation, the beans are dried, cleaned and then roasted and the shell is removed to produce cacao nibs. The nibs are then ground to cocoa mass, pure chocolate. This **cocoa mass** is liquified, called **chocolate liquor.** This liquor is processed into **cocoa solids** and **cocoa butter**. Much of the chocolate consumed today is in the form of sweet chocolate by the addition of milk powder or condensed milk. White chocolate contains cocoa butter, sugar and milk but no cocoa solids. Dark chocolate is produced by adding fat and sugar to the cacao mixture. Unsweetened chocolate is pure chocolate liquor, also known as **bitter or baking chocolate**. The chocolate industry is booming worldwide and chocolates are one of the most popular gifts.

Potpourri

It is a mixture of dried, naturally fragrant plant material used to provide a gentle natural scent in houses. In English, potpourri refers to any collection of miscellaneous or diverse items. The naturally scented plants used in traditional potpourri includes; allspice, cinnamon bark, cloves, fennel, jasmine flowers, lavender leaves, lemon peel, mint leaves, rose flowers, orange peel and many more. Modern potpourri consists of any decoratively shaped dried plants (not necessarily scented plant) with strong synthetic perfumes. Around 300 species from 95 families including fungi and lichens are used. In ceramic manufacturing also potpourri is being used.

Cosmetic, Toiletry and Perfume Industry

Today cosmetics, perfumes and skin care products constitute a multi-million dollar industry. Plant extracts are used for treating dry skin, eczema, acne, anti-aging, anti-inflammatory, skin protection and dandruff. *Aloe vera* has fast become one of the most commonly used plants in herbal cosmetics and medicines. Aroma therapy and spas are becoming an upcoming trend. The essential oils extracted from plants are used in soaps, shampoos and incense sticks. Herbal colors and dye are commonly used.

Herbal Medicine

The art of herbal medicine is very ancient, probably as old as human existence. There has been a shift in universal trends from synthetic to herbal medicine. Today, people around the world prefer alternative medicines such as ayurveda, naturopathy, homeopathy and herbal medicines. The demand of plant based medicines, health products, pharmaceuticals, food supplements and cosmetics are increasing in both developed and under-developed countries. In India about 1400 herbal preparations are used widely. The export of medicinal plants from India has increased 20% in the recent past. Currently India is heading towards the golden age of herbal medicines usage.

GLOSSARY

Abscission: The dropping off of leaves, flowers, fruits or other plant parts; an abscission zone is formed prior to abscission, which breaks the connection of that part with the plant.

After ripening: The metabolic changes that must occur in some dormant seeds before germination can occur.

Aggregate fruit: A fruit developed from the several separate carpels of a single flower.

Algin: An important polysaccharide component of brown algal cell walls; used as a stabiliser and emulsifier for some foods and paints.

Allele: The alternate forms of a genetic character found at a given locus on the chromosome.

Allelopathy: The inhibition of one species of a plant by chemicals produced by another plant.

Allopatric speciation: The formation of two species from one when reproductive isolation occurs because of the interposition of a physical geographic barrier such as a river.

Allopolyploidy: The possession of more than two complete set of chromosomes that are derived from a single species.

Anatomy: The study of the internal structure of organisms.

Annual ring: In wood, the growth layer formed during a single year; these rings are formed due to differential activity of cambium in different seasons.

Anthocyanin: A water-soluble blue or red pigment found in cell sap; the color of petals in some flowers and fruits is due to anthocyanin.

Apical dominance: The effect of terminal bud in suppressing the growth of lateral or axillary bud.

Apomixis: Reproduction without meiosis or fertilisation.

Apoptosis: The programmed cell death.

Archaea: A phylogenetic domain of prokaryotes consisting of the methogens, most extreme halophiles and hyperthermophiles and *Thermoplasma.*

Archegonia: The structure in which eggs are produced in non-vascular and several groups of vascular plants.

Aril: An accessory seed covering often formed by an outgrowth at the base of the ovule; often brightly colored, which aid in dispersal by attracting animals. The edible portion in Litchi fruit is the aril.

Artificial selection: The breeding of selected organisms to produce strain with desired characters.

Asci: The sac like structure that enclose the sexual spores of sac fungi.

Bacterial source tracking: To identify the source of dangerous bacteria in a stream or other water body by using molecular biological techniques.

Bacteriophage: A virus that parasitises bacteria.

Bark: The tissue outside vascular cambium in woody trees.

Basidia: The club-shaped structures on which sexual spores are produced in club-fungi.

Berry: A simple fleshy fruit that includes a fleshy ovary wall and one or more carpels and seeds; fruits of grapes, tomatoes and banana.

Biennial: A plant that requires two growing seasons to complete its life cycle.

Bioaccumulation: The buildup of a toxic substance in an organism's body, often in fatty tissues, also called bioconcentration.

Bioluminescence: Any organism flashing with fluorescent light by way of ATP-driven reactions involving enzyme (luciferase).

Biotechnology: The practical application of advances, made in understanding the processes and molecules of life, to manipulate the genetics of living organisms.

Bract: A modified, usually reduced leaf like structure.

Brown algae: The multicellular algae formerly classified with the plants; mostly marine; ranges in size from microscopic to giant multi-celled kelps.

Bryophytes: The amphibians of plants; non-vascular land plants requiring free water at the time of fertilisation; the members of non-vascular plants; the mosses, hornworts and liverworts.

Burgess shale: It is one of the most diverse and well-preserved fossil localities in the world, found in the area of the Canadian Rocky Mountains known as the Burgess Pass; sedimentary rocks there contain many fossils of Cambrian organisms.

Callus: Undifferentiated mass of cell; a term used in tissue culture, grafting and wound healing.

Calmodulin: A calcium-binding protein found in all animals and plant cell; mediates many other calcium-regulated processes.

Cambium: A meristem that gives rise to parallel rows of cells; responsible for secondary growth in plants.

Capsid: The protein coat of a virus particle.

Carotenoids: The fat soluble pigments that include the carotenes (yellow and orange pigments) and the xanthophylls (yellow pigments) found in chloroplast and chromoplast of plants. Carotenoids act as accessory pigments in photosynthesis, impart color to flowers and fruits (carrots are red due to cartenoids).

Caryopsis: Simple, dry, one seeded indehiscent fruit with fused ovary wall; a grain characteristic of the grasses and cereals.

Catkin: A spike like inflorescence of unisexual flowers; found only in woody plants.

Cellulose: A carbohydrate, the chief component of the cell wall of plants and some protists; an insoluble complex carbohydrate formed of microfibrils of glucose molecules attached end to end.

Central dogma: The statement that information flows from DNA to RNA to polypeptide.

Chemolithotroph: An organism that uses carbon dioxide as carbon source and obtains energy by oxidising inorganic substance from its environment.

Chimaeras: An organism, organ, or part consisting of two or more tissues of different genetic composition.

Chitin: A tough, resistant, nitrogen-containing polysaccharide forming the cell walls of certain fungi, the exoskeleton of arthropods, and the epidermal cuticle of other surface structures of certain protists and animals.

Chlorosis: Loss or reduced development of chlorophyll.

Circadian rhythm: A rhythm in behavior, growth or some other activity that recurs after 24 hours.

Cladogram: A lines diagram that branch repeatedly, suggesting the relationship among organisms.

Cladophyll: A branch resembling a foliage leaf.

Club mosses: Vascular plants characterised by microphylls.

Co-dominance: A condition in which two alleles at a locus produce different phenotypic effects and both effects appear in heterozygotes.

Codon: Three nucleotides in mRNA that directs the placement of a particular amino acid in a polypeptide chain.

Coleoptile: A sheath that surrounds and protects the shoot apical meristem and young primary leaves of a grass seedling.

Compensation point: The light intensity at which the rate of photosynthesis and cellular respiration are equal.

Complementary DNA (cDNA): A single stranded molecule of DNA that has been synthesised from mRNA template by reverse transcription.

Constitutive genes: Genes that encode protein that are needed at all times to maintain life; such genes are not regulated.

Convergent evolution: The independent evolution of similar feature from different ancestral traits; the development of similar structures with similar functions in different species.

Coral reef: The structure built from accumulated layers of calcium carbonates; found in warm, shallow sea water. Red coralline algae or colonies of millions of tiny coral animals reside in these reefs.

Cotyledon: In seeded plants a structure that absorbs, stores and distributes nutrients.

Crop rotation: The practice of growing different crops in regular succession to aid in the control of insects and diseases, to increase soil fertility and to decrease erosion.

Cryptogam: A general name for plants, and plant like organisms that lack flowers and are not reproduced by seeds, e.g., ferns, mosses, fungi and algae.

Cultivar: A variety of plant found only under cultivation.

Diatoms: A unicellular algae that looks like microscopic pillboxes because they are made up of top and bottom shells that fit together.

Dinoflagellates: A unicellular algae with stiff outer covering; they possess two unequal flagella, these are set into grooves.

Disruptive selection: A type of natural selection that occurs when two or more extreme phenotypes are fitter than the intermediates, and the population separates into increasingly different groups.

DNA chip (DNA microarrays): A small glass or plastic square onto which thousands of single stranded DNA sequences are fixed. Hybridisation of cell derived RNA and DNA to the target sequence can be performed.

Double fertilisation: Unique to angiosperms, a process in which the nuclei of two sperms fertilises one egg. One sperm's nucleus combines with the egg nucleus to produce a zygote while the other combines with the same egg's two polar nuclei to produce the first cell of triploid endosperm.

Drupe: A simple, fleshy fruit, derived from a single carpel, usually one-seeded, in which the inner fruit coat is hard and may adhere to the seed.

Endo-symbiotic theory: This theory explains the origin of eukaryotic organelles. The bacteria become attached to or engulfed by host prokaryotic cell; mitochondria are thought to have originated from aerobic bacteria and chloroplasts from photosynthetic bacteria.

Evolutionary synthesis (modern synthesis): It involves Darwin's theory of the evolution of the species and Mendel's theory of genetics as the basis for biological inheritance; recognise that mechanisms in addition to natural selection are integral to evolution.

Evolutionary tree: The depiction of the evolutionary history of an organism(s).

Exon: A portion of a DNA molecule, in eukaryotes that codes part of a polypeptide.

F_1(First Filal Generation): The immediate progeng of a parental (P) mating.

F_2(Second Filal Generation): The immediate progeny of mating between members of F_1 generation.

Fibre: An elongated, tapering, generally thick-walled sclerenchyma cell of vascular plants; its wall may or may not be lignified; it may or may not have living protoplast at maturity.

Flavonoids: Phenolic compounds; water soluble pigments present in the vacuoles of plant cells; those found in red wines and grape juice; supposed to lower cholesterol levels in blood.

Fruiting body: Any structure that bear spores.

Fucoxanthin: A brownish carotenoid found in brown algae and chrysophytes.

Functional Genomics: The assignment of functional roles to genes first identified by sequencing entire genomics.

Gametangium: Any plant or fungal structure within which a gamete is formed.

Gamete: The mature sexual reproductive cell—the egg or sperm.

Gametogenesis: The specialised series of cellular divisions that leads to production of sex cells (gametes).

Gametophyte: In plants and photosynthetic protists with alteration of generations, the multi-cellular haploid phase that produces the gamete.

Gene amplification: Creation of multiple copies of a particular gene, allowing the production of large amounts of the RNA transcript.

Gene cloning: Formation of a clone of bacteria or yeast cells containing a particular foreign gene.

Gene expression: The process by which genes produce protein and exert their effects on the organism.

Gene family: A set of identical (or once identified) genes derived from a single parent gene; need not be in the same chromosome. The vertebrate globin genes constitute a classical example of a gene family.

Gene flow: Exchange of genes between different species or between different populations of the same species caused by migration followed by breeding.

Gene library: A collection of clones of DNA fragment which together represents the entire genome of the organism; the cloned DNA fragments generated by action of a restriction endonuclease.

Gene pool: All genotypes in a population; all the alleles of all the genes of all the individuals in a population.

Gene therapy: Treatment of a genetic disease by providing patients with cells containing functioning alleles of the genes those are non-functional in their bodies.

Genetic counselling: The advice by geneticist to the couple, on the basis of their genetic history, at the time of pregnancy to determine if their offspring may be at risk of genetic disorders.

Genetic drift: Changes in gene frequencies from generation to generation as a result of random processes.

Genetic map: The positions of genes along a chromosome as revealed by recombination frequencies.

Genetic screening: The application of medical tests to determine whether an individual carries specific alleles.

Genetic stochasticity: Random variation in the frequencies of alleles and genotypes in a population over time.

Genomics: A branch of genetics that involves mapping sequencing and analysing the functions of the entire genome.

Genomic library: A collection of clones of DNA fragments, which together represent the entire genome of an organism.

Genomic imprinting: When a given gene's phenotype is determined by whether that gene is inherited by male or the female parent.

Ground meristem: The part of an apical meristem that gives rise to the ground tissue system of the primary plant body.

Guttation: The extrusion of liquid water through openings in leaves, caused by root pressure.

Heat-shock proteins: Chaperone proteins expressed in cells exposed to high or low temperatures or other forms of environmental stress.

Hemizygous: In a diploid organism, having only one allele for a given trait, typically the case for X-linked genes in male mammals and Z-linked genes in female birds.

Heterochrony: Comparing different species, an alteration in the timing of developmental events, leading to different results in the adult.

Heterocyst: A large, thick-walled cell in the filaments of certain cynobacteria; perform nitrogen fixation.

Heterokaryon: In fungi, hypha containing two genetically different nuclei.

Heteromorphic: Having a different form and appearance, as two heteromorphic life stages of a plant.

Heterosis: Situation in which heterozygous genotypes are superior to homozygous genotypes with respect to growth, survival or fertility; also called hybrid vigor.

Homeotic genes (master control gene): Genes that determine the developmental fete of entire segments of an organism.

Hornworts (Anthocerophyta): Non-vascular plants with elongated sporophytes that protrude like horns from the creeping gametophyte. Cell contains a single large, plate-like chloroplast.

Human genome project: A worldwide scientific project that deciphers the DNA code of all 46 chromosomes.

Humus: The partly decomposed remains of plants and animals on the surface of a soil.

Hybridoma: A cell produced by the fusion of an antibody-producing cell with a myeloma cell; it produces monoclonal antibodies.

Imbibition: Water uptake by a seed; first step in germination.

Imperfect fungi: The deutromycetes, or conidial fungi, which reproduce only asexually or in which the sexual cycle has not been observed.

Indicator species: An organism that provides an early warning of environmental damage. Examples include lichen, which are sensitive to air pollution, and amphibians, which are sensitive to pesticides and other environmental contamination.

Integrase: An enzyme that integrates retroviral cDNA into the genome of the host cell.

Interference RNA (RNAi): A mechanism for reducing mRNA translation whereby a double-stranded RNA, made by the cell or synthetically, is processed to a small, single stranded RNA, and binding of this RNA to a target mRNA results in the latter's breakdown.

Interferon: A glycoprotein produced by viral infected animal cells; increases the resistance of neighboring cells to virus.

Internode: The region between two nodes of the stem.

Intron: A portion of DNA molecule that, because of RNA splicing, is not involved in coding the part of a polypeptide molecule.

Jasmonates: Plant hormones that trigger defenses against pathogens and herbivorous.

Karyotype: The arrangement of chromosomes according to their size, shape and position of centromere.

Kin selection: The component of inclusive fitness resulting from the survival of relatives containing the same alleles by descent from a common ancestor.

Knock out: A molecular genetics method in which a single gene of an organism is permanently inactivated.

Kranz anatomy: The wreath like arrangement of mesophyll cells around a layer of large bundle sheath cells, forming two concentric layers around the vascular bundle; typically found in the leaves of C_4 plants.

Laminarin: One of the principal storage products of the brown algae; a polymer of glucose.

Lateral gene transfer: The transfer of gene from one species to another, common among bacteria and archaea.

Lichens: The association between sac fungi and either cynobacteria or green algae.

Life table: A table showing for a group of equal aged individuals, the proportion still alive at different times in the future and the number of offspring they produce during each time interval.

Liverworts: They are small, green, non-vascular plants of the division Marchantiophyta.

Mangrove forest: Swamps of mangrove trees that grow along many tropical coasts.

Matrotrophy: A form of nutrition provided by the maternal gametophyte as in the case of a moss gametophyte providing nutrients to the zygote and developing sporophyte.

Monoculture: The cultivation of only one type of plant over a large area.

Monohybrid cross: A cross between parents who are heterozygous for one gene.

Monokaryotic: In fungi, having a single haploid nucleus within one cell or compartment.

Mutation: The change in genetic material that alter(s) the original gene(s) expression; It can affect a single gene, fragment of a chromosome or the entire sets of chromosome.

Nastic movements: The plant movements in which direction of the response is not related to the direction of the stimulus.

Nectary: A gland that secretes nectar, a sugary fluid that attract animals to plants.

Necrosis: Death of many cells that result from severe tissue damage.

Neo-Darwinian theory of evolution: A genetically based view of natural selection developed in the early twentieth century.

Node: The positions on stem of a plant where leaves are formed.

Non-random mating: The selection by individuals of other individuals of particular genotypes as mates.

Non-vascular plants: Those plants lacking well developed vascular tissues; the liverworts, hornworts and mosses.

Normal microbiota: The bacteria that usually inhibit the human body in places such as mouth, throat, colon, vagina and skin; such bacteria do not cause disease and prevent other bacteria to invade the body.

Null hypothesis: The assertion that an effect proposed by its companion hypothesis does not in fact exist.

Nut: A dry indehiscent, hard, one-seeded simple fruit, generally produced from a gynoecium of more than one fused carpel.

Obligate anaerobe: An anaerobic prokaryote that cannot survive exposure to O_2.

Okazaki fragment: In DNA replication, the discontinuous segments in which the 3' to 5' strand (the lagging strand) of the DNA double helix is synthesised; typically 1000–2000 nucleotides long in prokaryotes and 100–200 nucleotides long in eukaryotes.

Oncogene: Gene that greatly stimulate cell division, giving rise to tumors.

Ontogeny: The development, or life history, of all or part of an individual organism.

Orthology: A type of homology applied to the genes in which the divergence of homologous genes can be traced to speciation events. The genes are said to be orthologus, and each is an ortholog of the others.

Ovule: A structure in seed plants containing the female gametophyte with egg cell, all being surrounded by the nucellus and one or two integuments; when mature, an ovule becomes a seed.

Paleobotany: The study of fossil plants.

Parallel evolution: Repeated evolutionary patterns of change that occur independently in multiple lineages.

Paralogy: A type of homology applied to the genes in which the divergence of homologous gene can be traced to gene duplication events. The genes are said to be paralogous and each is a paralog of the others.

Parapatric speciation: Reproductive isolation between subpopulations arising from some non-geographic but physical conditions, such as soil nutrient content.

Paraphyletic: Referring to a group that consists of an ancestor and some of its descendants.

Parsimony: The principle of preferring the simplest among a set of plausible explanations of any phenomenon.

Parthenocarpy: Formation of fruit from a flower without fertilisation.

Particulate theory: In genetics, the theory that genes are physical entities that retain their identities after fertilisation.

Pectin: A highly hydrophilic polysaccharide present in the intercellular layer and primary wall of the plant cell walls; the basis of fruit jellies.

Pedigree: The pattern of transmission of a genetic trait within a family; Diagram of genetic connections among related individuals through successive generations; uses standardised symbols.

Perennial: A plant in which the vegetative structure live year after year.

Perfect flower: A flower with both stamens and carpels.

Petiole: The cylindrical stalk of the leaves.

Phenotypic plasticity: Refers to the fact that the phenotype of a developing organism is determined by a complex series of processes that are affected by both its genotype and environment.

Pheromone: A chemical substance used in communication between organisms of the same species.

Photochemical smog: A type of air pollution caused by reactions between hydrocarbons and nitrogen oxides in the presence of sunlight.

Photoperiodism: The effect of relative lengths of light and dark cycles on plant growth and development; a mechanism evolved by organism for measuring seasonal time.

Phylogeny: The evolutionary history of an organism.

Phytoalexins: Substances toxic to pathogens, produced by plants in response to fungal or bacterial infection.

Phytochromes: The photoreceptor pigments in plants that absorb red and far red light.

Pigments: The molecules that absorb some visible wave length of light.

Plasmid: Relatively small fragments of DNA that can exist free in the cytoplasm of a bacterium and can be integrated into and then replicated with a chromosome; it is 5% of the DNA of many bacteria.

Plasmodial (acellular) slime moulds: These organisms have an ameboid stage in their life cycle. They spend much of their time as a non-walled, multinucleate mass of cytoplasm called a plasmodium; they can form spores when food or moisture is in short supply.

Plasmolysis: The separation of protoplast from the cell wall because of the removal of water from the protoplast by osmosis.

Pleiotropy: The determination of more than one character by a single gene.

Pneumatophores: The negative geotropic extensions of roots of some of the trees growing in swampy habitats; they grow upward and out of the water to ensure adequate aeration.

Pollination: The transfer of pollen from an anther to stigma.

Polyembryony: Presence of more than one embryo in the developing seed.

Polyphyletic: Referring to a group that consists of multiple distantly related organisms, and does not include the common ancestor of the group.

Pome: A simple fleshy fruit, the outer portion of which is formed by the floral parts that surround the ovary and that expands with the growing fruit; found in the subfamily of *Rosaceae* (apple, pears and quince, etc.)

Positional cloning: A technique for isolating a gene associated with a disease on the basis of its approximate chromosomal location.

Primary growth: Plant growth originating at root tips and shoots tips.

Primary metabolites: Molecules that are found in all plant cells and are necessary for the plant; e.g., simple sugars, amino acids, proteins and nucleic acids.

Prions: Small infectious proteins that cause rare, fatal degenerative diseases of nervous system.

Prop roots: Adventitious roots arising from the stem above soil level and helping to support the plant; common in many monocots, e.g., maize.

Proteome: The sum total of different proteins that can be made by an organism. Because of alternate splicing of pre-mRNA, the number of proteins that can be made is usually much larger than the number of protein-coding genes present in the organism's genome.

Prototroph: (The nutritional wild type, or reference from, of an organism.) Any deviation from that requires growth nutrients not required by the prototrophic form is said to be a nutritional mutant or auxotroph.

Pseudogene: A DNA segment that is homologous to a functional gene but is not expressed because of changes to its sequence or changes to its location in the genome.

Punnett square: A method of predicting the results of genetic cross by arranging the gametes of each parent at the edge of square.

Quantasome: Granules located on the inner surfaces of the chloroplast lamellae.

Quiescent center: In root meristem, central region where cells do not divide or divide very slowly.

R genes: Resistance genes that function in plant defenses against bacteria, fungi and nematodes.

Raceme: An indeterminate inflorescence in which the main axis is elongated but the flowers are borne on pedicels that are equal in length.

Random mating: Each member of the population has an equal opportunity of mating with every member of the opposite sex.

Raphides: Fine, sharp, needle-like crystals of calcium oxalate found in the vacuoles of many plant cells.

Reciprocal crosses: A pair of mating in one of which a female of genotype A mates with a male of genotype B and in the other of which a female of genotype B mates with a male of genotype A.

Regulator gene: A gene that prevents or represses the activity of structural gene.

Reporter gene: A marker gene included in recombinant DNA to indicate the presence of the recombinant DNA in a host cell.

Repressor: A protein that regulates DNA transcription.

Restriction enzymes: The enzyme that cleaves DNA double helix at specific nucleotide sequences.

Restriction fragment length polymorphism (RFLP): Coexistence of two or more patterns of restriction fragments (patterns produced by restriction enzymes), as revealed by a probe. The polymorphism reflects a difference in DNA sequence on homologous chromosome.

Restriction site: A specific DNA base sequence recognised and acted on by a restriction endonuclease cutting the DNA.

Reverse transcriptase: An enzyme that catalyses the production of DNA (cDNA), using RNA as template; essential to the reproduction of retrovirus.

Rhizoids: Branched root like extensions of fungi and algae that absorb water, food and nutrients. In liverworts and mosses and some vascular plants they are the root-hair like structures.

Rhizome: A horizontal underground stem.

Ribozyme: An RNA molecule with catalytic activity.

RT-PCR: A technique in which RNA is first converted to cDNA by the use of enzyme reverse transcriptase, then cDNA is amplified by polymerase chain reaction.

Samara: A simple, dry, one-seeded or two-seeded indehiscent fruit with wing-like outgrowth.

Scarification: The process of cutting or softening hard seed coat to promote seed germination.

Schizocarp: A dry simple fruit with two or more united carpels that split apart at maturity.

Sea grasses: Flowering plants that grow in quiet, shallow ocean water in temperate, subtropical and tropical waters.

Secondary metabolites: Molecules that are restricted in their distribution, both within the plant and among different plants; important for survival and propagation of the plants that produce them; there are three major types—alkaloids, terpenoids and phenolics; also called as secondary products.

Sex-linked alleles: The alleles found on X or Y chromosome; almost all sex-linked alleles causes sex-linked disorder and are found on the X chromosome.

Sexual selection: A form of natural selection that depends on the struggle between the individuals of one sex for mates of the other sex.

Shotgun sequencing: A relatively rapid method of analysing DNA sequence in which a large DNA molecule is broken up into overlapping fragments, each fragment is sequenced, and computers are used to analyse and realign the fragments.

Sigmoid growth curve: The exponential growth of a population and its subsequent stabilisation at the level of its environment's carrying capacity.

Silique: A two-celled, valve splitting from the bottom; the fruit characteristic of the mustard family.

Sink: In plants, any organ that imports the products of photosynthesis, such as roots, developing fruits and immature leaves.

Sociobiology: The biology of social behavior; this field applies the knowledge of evolutionary biology to the study of animal behavior.

Solar tracking: The ability of the leaves and flowers of many plants to move diurnally, orienting themselves to the sun's direct rays; also known as heliotropism.

Source: In plants, an organ exporting photosynthetic products in excess of its own needs.

Speciation: The formation of a daughter species from a population or subpopulation of a parent species by way of microevolutionary processes.

Spliceosome: An RNA-protein complex that splice out introns from eukaryotic pre-mRNAs.

Splicing: The removal of introns and connecting exons in eukaryotic pre-mRNAs.

Sporocyte: Specialised cells of the diploid sporophyte that will divide by meiosis to produce four haploid spores. Germination of these spores produces the haploid gametophyte.

Sporopollenin: A cyclic alcohol present on the outer wall of the spores and pollen grains; it make them highly resistant to decay.

Stasis: Period during which little or no evolutionary change takes place within a lineage or groups of lineage.

Stolon: The horizontal stem that grows above the ground; also called runners.

Stomata: The openings in the epidermis of a leaf bordered by guard cells; stomata are responsible for gaseous exchange in the plants.

Stratification: The process of exposing seeds to lower temperatures for an extended period before germination.

Strobilus: A cone-like structure consisting of spore-bearing scales (modified leaves) inserted on an axis.

Structural gene: Any gene that codes for a protein; functional gene.

Survivorship: The proportion of an original population that lives to a certain age.

Systematics: The scientific study of the diversity of the organisms and their relationships; focusing on their evolutionary as well as comparative relationships.

Systemin: The only polypeptide plant hormone; participates in response to tissue damage.

Systems biology: The study of an organism as an integrated and interacting system of genes, proteins and biochemical reactions.

Taxis: The movement of an organism or its part directly towards or away from the stimulus, such as light, chemicals or heat.

Taxon: A named group of organisms, such as phylum, family or order.

Taxonomy: The branch of biology which deals with classifying, identifiying and naming the living organisms.

Test cross: Mating of a dominant-phenotype individual (who may be either heterozygous or homozygous) with a homozygous-recessive individual.

Thallus: Body which is not differentiated into root, stem and leaf, specially in algae.

Tissue: A group of similar cells that perform similar function and have a common origin.

Tissue differentiation: A developmental process in which groups of cells (tissue) become distinguished from other groups of cells.

Trait: One form of character.

Transformation: The mechanism of transfer of genetic information in bacteria.

Transgenic plants: Genetically modified plants; plants that are genetically altered using the techniques of genetic engineering.

Transpiration: The loss of water by the plants in the form of vapours through stomata, lenticels or cuticle.

Transpiration pull: The pull created by transpiration due to which the water moves from the soil through roots to the leaves.

Transposable element: A segment of DNA that can move from one locus to another locus on the same or different chromosome.

True breeding: A genetic cross in which the same result occurs every time with respect to trait(s), due to homozygous parents.

Variable number of tandem repeats (VNTRs): Short DNA sequences that are repeated a characteristic number of times in related individuals. It can be used to make DNA fingerprint.

Vascular bundle: A strand of vascular tissues having xylem and phloem.

Vector: A plasmid or virus that carries an inserted piece of DNA into a bacterium for cloning purposes in recombinant DNA technology.

Vernalisation: Cold treatment requirement for flowering.

Viroids: Small strands of RNA that replicates in the host cells like viruses; they can cause plant diseases.

Water molds: They are also called egg fungi. Fungus-like protists that pre-digest and absorbs food as fungi do; these grow in moist and aquatic environments.

Zeatin: A natural cytokinin isolated from maize.

Zygospores: The sexual spores formed by the zygote forming fungi.

151 (a)	152 (b)	153 (d)	154 (d)	155 (c)	156 (c)
157 (d)	158 (b)	159 (c)	160 (b)	161 (d)	162 (a)
163 (a)	164 (c)	165 (a)	166 (d)	167 (b)	168 (a)
169 (c)	170 (d)	171 (d)	172 (c)	173 (a)	174 (b)
175 (b)	176 (b)	177 (a)	178 (a)	179 (b)	180 (d)
181 (a)	182 (d)	183 (a)	184 (b)	185 (b)	186. (b)
187 (a)	188 (c)	189 (a)	190 (b)	191 (b)	192 (c)
193 (a)	194 (b)	195 (c)	196 (a)	197 (d)	198 (b)
199 (c)	200 (c)	201 (a)	202 (b)	203 (c)	204 (d)
205 (a)	206 (d)	207 (b)	208 (b)	209 (c)	210 (b)
211 (d)	212 (b)	213 (a)	214 (b)	215 (c)	216 (b)
217 (b)	218 (a)	219 (c)	220 (c)	221 (b)	222 (b)
223 (d)	224 (d)	225 (d)	226 (b)	227 (b)	228 (c)

MULTIPLE CHOICE QUESTIONS

1. The dividing cells treated with Colchicine are arrested at

   1. Sphase
   2. G_1phase
   3. Prophase
   4. Metaphase

   Select the correct answer using codes given below:

   (a) 1, 2 and 3
   (b) 2 and 4
   (c) 1 and 3
   (d) 4 only

2. Membrane of which of the following organelles are not contiguous?

   1. ER and Golgi
   3. Nucleus and ER
   2. Golgi and Plasma membrane
   4. Golgi and lysosome

   Select the correct answer using the codes given below.

   (a) 1 and 2
   (b) 1, 2 and 3
   (c) 1, 2 and 4
   (d) All of the above

3. Membrane potential across the membrane are caused by unequal distribution of

   1. Ions
   2. Fatty acids
   3. Glucose
   4. IP_3

   Select the correct answer using the codes given below.

   (a) Only 1
   (b) 1, 2 and 3
   (c) 1, 3 and 4
   (d) None of the above

4. The leaves of purple cabbage losses its colour on boiling because

   1. Boling water can enter the cell cavity
   2. Plasma lemma gets killed in boiling water
   3. Cell wall is killed in boiling water
   4. The pigment is not soluble in cold water

   Which of the statements given above is/are correct?

   (a) 1 only
   (b) 2 only
   (c) 1 and 3 only
   (d) All of the above

5. Which of the following process (es) require energy?

   1. Pinocytosis
   2. Na^+-K^+ pump
   3. Phagocytosis
   4. All

   Select the correct answer using codes given below.

   (a) 1 and 2
   (b) 1 and 3
   (c) 2 only
   (d) 4 only

6. Diffusion across the plasma membrane is more rapid if a substance is

   1. A protein
   2. Hydrophilic
   3. High in its oil : water partition coefficient
   4. Large and globular in shape

   Select the correct answer using the codes given below.

   (a) 1, 2 and 4
   (b) 1 and 4
   (c) 2 only
   (d) All of the above

7. Protein "expansion" present in cell wall helps in

   1. Cell elongation
   2. Cell division
   3. Molecular organisation

   Select the correct answer using the codes given below.

   (a) 1 only
   (b) 2 and 3 only
   (c) 1 and 3 only
   (d) 1, 2 and 3 only

8. In the presence of light chloroplast's thyllakoid lumen pH will

   (a) Increase
   (b) Remain the same

(c) Decrease
(d) Depend on the status of the cell

9. Which of the following organelles do not change its shape?
   1. Chloroplast 2. Mitochondria
   3. Peroxisome 4. Nucleus

   Select the correct answer using the codes given below.
   (a) 1, 2 and 3 (b) 1, 3 and 4
   (c) 1 and 4 (d) All of the above

10. The proper folding of protein is done by
    1. Chaperone 2. Ligase
    3. Kinase 4. Troponine

    Select the correct answer using the codes given below.
    (a) 1 only (b) 2 only
    (c) 1 and 3 only (d) None of the above

11. The most useful colors of light for photosynthesis are
    (a) Green, yellow and orange
    (b) Red, violet and blue
    (c) Infrared, red and yellow
    (d) Red, white and blue

12. Thomas Engelman illuminated a filament of algae with light that passed through a prism. He added aerobic bacteria and found that these bacteria congregated in the areas illuminated by red and blue light. If the same experiment is done without passing the light through a prism, what will happen?
    (a) There would be no difference in results.
    (b) The number of bacteria would decrease along the entire length of the filament.
    (c) The bacteria would be relatively evenly distributed along the length of the filament.
    (d) The number of bacteria would increase along the entire length of the filament.

13. *Chlorella* is a suitable plant for astronauts in space because
    1. It provides oxygen to the astronaut and carbon dioxide released is utilised for its photosynthesis
    2. It supplies abundant food to the astronaut
    3. It is a single celled autotrophic plant and slow growing
    4. Its growth is quite rapid during space flight

    Which of the statements given above is/are correct?
    (a) 1 only (b) 2 and 3
    (c) All of the above (d) None of the above

14. In Crassulacean Acid Metabolism (CAM) plants
    1. Phoshoenolpyruvate carboxylase reduces CO_2 to make malic acid.
    2. Stomata open only during the day.
    3. Vascular tissue is surrounded by a bundle sheath.
    4. Rubisco is activated only at night.

    Which of the statements given above is/are correct?
    (a) 1 only (b) 2 only
    (c) 3 and 4 only (d) All of the above

15. Bacteria cannot survive in a highly salted pickle because
    1. Salt inhibits reproduction.
    2. Bacteria do not get enough light for reproduction.
    3. They get plasmolysed and are killed.
    4. The pickle does not contain nutrients necessary for bacteria to live.

    Which of the statements given above is/are not correct?
    (a) 1, 2 and 3 (b) 1 only
    (c) 1, 2 and 4 only (d) 3 and 4 only

16. Myrmecophilly is a beneficial association between some flowering plants and
    (a) Bacteria (b) Ants
    (c) Virus (d) Mycoplasma

17. "Taxol" used as an anticancer drug; it is obtained from which part/s of the plant?
    1. Root 2. Leaf
    3. Bark 4. Seed

    Select the correct answer using codes given as follows.

(a) 1 only (b) 1 and 2 only
(c) 3 only (d) All of the above

18. The difference in asexual and sexual reproduction is that
    (a) Asexual reproduction produces identical copies
    (b) Sexual reproduction leads to variation
    (c) In Asexual reproduction one parent alone produces offspring
    (d) All of the above

19. The expression of a given gene depends on
    1. Type of cell and its function
    2. Chemical conditions
    3. Environment signal

    Select the correct answer using the codes given below.
    (a) 1 only (b) 2 and 3
    (c) 1 and 2 (d) 1, 2 and 3

20. Algin used in ice creams, puddings, toothpaste and other product is obtained from
    1. Green algae 2. Brown algae
    3. Dinoflagellates 4. Red algae

    Select the correct answer using the codes given below:
    (a) 1 and 2 only (b) 2 only
    (c) 1 and 4 (d) All of the above

21. When fungi die, trees lose their vital support system because
    1. Fungi are associated with young tree roots.
    2. They help the trees to survive seasonal shifts in temperature and rainfall.
    3. These fungal hyphae penetrate in the plant cells.
    4. Fungi do not allow other pathogen to grow.

    Which of the above given statements is/are false?
    (a) 1 and 2 only (b) 2 only
    (c) 2, 3 and 4 only (d) All of the above

22. Plants keep track of day length. This timing mechanism is called
    (a) Biological Clock (b) Photoperiodism
    (c) Phototropism (d) Circadian Rhythm

23. Which of the following is/are paired correctly?
    1. Auxin// seed germination
    2. Phytochrome// photoperiodic control of flowering
    3. Abscisic acid// fruit ripening
    4. Ethylene// phototropism

    Select the correct answer using the codes given below.
    (a) 1 only (b) 2 only
    (c) 1 and 3 only (d) None of the above

24. Which of the following responses to the environment are controlled by plant hormones?
    1. Growth response to gravity
    2. Growth response to light
    3. Dropping of leaves in the fall

    Select the correct answer using the codes given below.
    (a) 1 and 2 only (b) 1 and 3 only
    (c) 2 and 3 only (d) 1, 2 and 3

25. Which Vitamin is prevalent in oranges?
    (a) Vitamin A (b) Vitamin B
    (c) Vitamin C (d) Vitamin D

26. In 1953, which two scientists determined that the structure of DNA is double helix?
    (a) Rosalind Franklin and Watson
    (b) Watson and Crick
    (c) Crick and Rosalind Franklin
    (d) Watson and Chargaff

*27. Which one of the following is the correct sequence in the decreasing order of production (in million tonnes) of the given food grains in India?
    (a) Rice-Wheat-Coarse cereals-Pulses
    (b) Wheat-Rice-Pulses-Coarse cereals
    (c) Rice-Wheat-Pulses-Coarse cereals
    (d) Wheat-Rice-Coarse cereals-Pulses

28. Which bacterium is responsible for making armpit smelly?
    (a) *Corynebacterium* (b) Bacillus
    (c) Spirillum (d) *E.coli*

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* Questions that have appeared in previous civil services examinations.

29. A red flower kept in green light will appear
    (a) Black (b) Green
    (c) Red (d) Blue

*30. *Dalbergia* species is associated with which one of the following?
    (a) Rosewood (b) Cashew nut
    (c) Tea (d) Coffee

31. The role of water in photosynthesis is:
    (a) It helps to make ATP.
    (b) It provides electron to fill electron "holes" in P680 molecule.
    (c) Water is not used at all in photosynthesis.
    (d) It carries electron to the light independent reaction.

32. Carbohydrate produced during photosynthesis may be used for which of the following?
    (a) Transformed into a structural polysaccharide such as cellulose
    (b) Used to fuel cellular respiration
    (c) Combined with other plant nutrients and converted into proteins and DNA
    (d) All of the above

33. Which of the following statements is/are true?
    1. Plants produce sugar but don't use them in metabolism; animals consume and use sugars in metabolism but cannot produce it.
    2. Plant cells undergo only photosynthesis; animal cells undergo cellular respiration.
    3. Plant cells produce only O_2 from metabolism; animal cells produce only CO_2 from metabolism.
    4. Plant cells have both mitochondria and chloroplasts; animal cells have only mitochondria.

    Select the correct answer using the codes given below.
    (a) 1 only
    (b) 1 and 2 only
    (c) None of the above
    (d) 4 only

34. The roots of plants are not exposed to sunlight. How do they manufacture ATP?
    (a) They do not need ATP.
    (b) They respire and make ATP.
    (c) The sucrose synthesised in the leaf is transported to root and is metabolised and ATP is released.
    (d) None of the above.

35. If a plant is wrapped in transparent green or blue cellophane and set in sunlight, how will it affect photosynthesis?
    (a) Plant wrapped in green paper will not be able to photosynthesis.
    (b) Plant wrapped in blue paper will have more photosynthesis as compared to white light.
    (c) Plant wrapped in green paper will have more photosynthesis as compared to plant wrapped in blue paper.
    (d) There will be no change in the rate of photosynthesis in both the plants wrapped with green and blue paper.

36. Why are sprouts healthier than the boiled form of the same seed?
    (a) Sprouting increases activity of hydrolytic enzymes.
    (b) Sprouting increases crude fibre content.
    (c) Sprouting increases essential fatty acids and vitamin.
    (d) All the above.

37. *Darwinian Fitness* means that organisms have
    1. More physical strength
    2. Ability to survive and reproduce
    3. Strong healthy appearance

    Which of the above given statements is/are correct?
    (a) 1 only (b) 2 and 3 only
    (c) 1 and 3 only (d) 1, 2 and 3

38. Evolution can be defined as
    1. A change in the environmental condition
    2. A change in the genetic makeup of an organism due to mutation

3. A change in the physical appearance of an organism
4. The process of change over time by which the population develops from ancestral forms through modification of their characteristics

Which of the above given statements is/are correct?

(a) 1 and 2 only (b) 1and 3 only
(c) 2 and 3 only (d) 4 only

39. Which of the following would be considered as alive?
    1. A carrot that has been refrigerated for a week
    2. The wood in a fallen tree branch
    3. An apple seed
    4. A frozen embryo

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 4 only (d) 1, 3 and 4 only

40. An example of the most important property of a living being is
    (a) Populations of organisms change over time.
    (b) Producers are consumed by consumers.
    (c) Structures of organisms fit their functions.
    (d) An organism is more than a collection of cells.

41. Match the following:

Name of the Organism	**Mode of Nutrition**
A. Amoeba	1. Autotrophic
B. Mushroom	2. Parasitic
C. Green plant	3. Saprophytic
D. Mosquito	4. Holozoic

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	1	2
(c)	3	2	4	1
(d)	4	1	3	2

42. To demonstrate the leaves are the site of photosynthesis, starch test is done on a leaf. Why is it important to boil the leaf in alcohol?
    (a) To remove the chlorophyll
    (b) To stop chemical reaction in the cell
    (c) To dissolve the waxy coating
    (d) To make the cell permeable to iodine solution

43. If a plant is not photosynthesising during the day time, it will release
    1. Water vapors
    2. Carbon dioxide
    3. Oxygen

Select the correct answer using the codes given below.

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

44. In a woody stem the gaseous exchange takes place through
    (a) Stomata
    (b) Lenticels
    (c) No gaseous exchange at all
    (d) Cracks in the bark

45. The branches of a fallen tree (roots are still in contact with the soil) grow straight up. This response is due to
    1. Water 2. Minerals
    3. Light 4. Gravity

Select the correct answer using the codes given below.

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 3

46. The growth of tendrils in plants is due to
    (a) Rapid cell division and elongation in tendril's cells on contact with the support
    (b) Effect of sunlight on the tendril's cell
    (c) Rapid cell division and elongation in tendril's cells that are away from the support
    (d) Effect of gravity on the part of tendril hanging down towards the earth

47. Thigmotropism response in plants is due to

(a) Touch (b) Gravity
(c) Light (d) Chemical

48. Which of the following are not the tropical movements in the plants?
    1. Curling up of the leaves of sensitive plants in response to touch
    2. Coiling of tendrils around a support in response to touch
    3. Growing of pollen tube in response to sugary substance
    4. Opening of the leaves in some plants in response to light

    Select the correct answer using the codes given below.

    (a) 1 and 2 only (b) 1 and 3 only
    (c) 2 and 4 only (d) 1 and 4 only

49. Given below are the name of the organisms and mode of their propagation/reproduction.
    1. Spirogyra- budding
    2. Bryophyllum-leaves
    3. Potato-tubers
    4. Sugarcane-cuttings
    5. Yeast-fragmentation

    Which of the above given pairs are correctly matched?

    (a) 2, 3 and 4 (b) 1, 2, 3 and 4
    (c) 1, 3 and 5 (d) All of the above

50. Which of the following organisms reproduce by asexual method?
    1. Banana 2. Lily
    3. Mango 4. Potato

    Select the correct answer using the codes given below.

    (a) 1, 3 and 4 (b) 2 and 4
    (c) 1, 2 and 4 (d) 2, 3 and 4

51. The rapid spreading of bread mold on the slice of bread is due to
    (a) Presence of large number of spores in air
    (b) Formation of sporangia
    (c) Presence of moisture and nutrients
    (d) Presence of large number of thread like hyphae

52. Vegetative propagation is the formation of new plant from which of the following existing organs of the old plant?
    (a) Stem, root and flower
    (b) Stem, leaf and flower
    (c) Root, stem and leaf
    (d) Stem, flower and fruit

53. In an onion plant, the male gametes have 8 chromosomes; which of the following statements is/are true?
    1. The female gametophyte has 16 chromosomes.
    2. The root cells have 8 chromosomes.
    3. The zygote has 16 chromosomes.
    4. The scale leaves have 8 chromosomes.

    Select the correct answer using the codes given below.

    (a) All of the above (b) 1 and 2 only
    (c) 3 only (d) 1 and 4 only

54. The characters inherited by offspring from their parents during sexual reproduction show
    (a) Neither similarities nor variations with parents
    (b) Both similarities and variations with parents
    (c) Only similarities with parents
    (d) Only variations with parents

55. In a particular species the number of chromosome in parents and offspring remains constant due to
    (a) Reduction of chromosome into half after gamete formation
    (b) Doubling of chromosome after gamete formation
    (c) Reduction of chromosome into half during gamete formation
    (d) Doubling of chromosome after fertilisation

56. Which of the following statements is/are false for unisexual flowers?
    1. They posses either stamen or pistil.

2. They posses both stamen and pistil.
3. The flower having stamens and cannot produce fruits.
4. They exhibit cross pollination.

Select the correct answer using the codes given below.

(a) 2 only (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 4 only

57. Which of the following statements are not false for sexual reproduction in a flowering plant?
    1. It requires both the types of gametes.
    2. Fertilisation is an essential step.
    3. It always forms zygote after fertilisation.
    4. Offspring formed are different from parents.

    Select the correct answer using the codes given below.

    (a) 1, 2 and 4
    (b) All of the above
    (c) None of the above
    (d) 2, 3 and 4
58. The sequence of reproductive stages occurring in flowering plant is
    (a) Gametes, embryo, seed, zygote
    (b) Gametes, seed, embryo, zygote
    (c) Seed, embryo, zygote, gametes
    (d) Gametes, zygote, embryo, seed
59. Which of the following share the maximum characteristics?
    (a) Two genera of two different families
    (b) Two individual of a species
    (c) Two genera of a family
    (d) Two species of a genus
60. Consider the following statements:
    1. There is a gene for every hormone synthesis.
    2. There is a gene for the production of a polypeptide.
    3. Genes are responsible for synthesis of fats.
    4. Gene is a unit of heredity.

    Which of the above given statements is/are correct?

    (a) None of the above
    (b) 1 and 3
    (c) 1, 2 and 4 only
    (d) 1, 3 and 4 only
61. Some of the scientists and their field of contribution are given below.
    1. Watson -Physiology
    2. Gregor Mendel-Reproductive Biology
    3. Lamarck- Genetics
    4. Charles Darwin-Origin of Life
    5. Urey Miller- Evolution

    Which of the above given pairs are matched correctly?

    (a) All of the above
    (b) None of the above
    (c) 1, 3 and 5 only
    (d) 2, 3 and 4 only
62. The origin of new species occurs when
    1. Chromosome number changes in the gametes
    2. DNA gets mutated
    3. Mating does not take place with existing species
    4. There is no change in the genetic material

    Which of the above given statements is/are correct?

    (a) 2 and 3 (b) 1, 2 and 3
    (c) 2, 3 and 4 (d) 1, 3 and 4
63. The wings of cockroach and the wings of pigeon are example of
    1. Analogous organs
    2. Homologous organs
    3. Vestigial organs
    4. Flight muscles

    Select the correct answer using the codes given below.

    (a) 1 only (b) 2 only
    (c) 2 and 4 only (d) 1 and 3 only

*64. Which one of the following parts of the pitcher plant becomes modified into a pitcher?

(a) Stem (b) Leaf

(c) Stipule (d) Petiole

*65. Which one of the following is an insectivorous plant?

(a) Passion flower plant

(b) Pitcher plant

(c) Night queen

(d) Flame of the forest

*66. Consider the following statements about probiotic food:

1. Probiotic food contains live bacteria which are considered beneficial to humans.
2. Probiotic food helps in maintaining gut flora.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

67. Which of the following is/are not a drug/pharma company?

1. Pfizer 2. Zydus Cadila

3. Chevron 4. Nicolas Piramal

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 2, 3 and 4

(c) 3 only (d) 2 and 3 only

68. Which of the following fruit contains maximum anti-oxidants?

(a) Guava (b) Oranges

(c) Apple (d) Pears

69. Which of the following cereals is known as "American greatest gift to mankind"?

(a) Rice (b) Corn

(c) Wheat (d) Triticale

70. Name the "king of spices".

(a) Black Pepper (b) Clove

(c) Nutmeg (d) Cardamom

Directions: *Questions 71 and 72 consist of two statements, one labelled the 'Assertion A' and the other labelled the 'Reason R'. Examine the two statements carefully and decide if the Assertion A and the Reason R are individually true and if so, whether the Reason is correct explanation of the Assertion. Select your answers to these questions from the codes given below.*

(a) Both A and R is true and R is correct explanation of A.

(b) Both A and R is true and R is not correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

71. **Assertion (A):** Molecular technology has made it possible to insert human gene into the DNA of bacteria. The bacteria take up the gene and are able to transcribe and translate and form the desirable product.

Reason (R): There are fundamental similarities in bacteria and human transcription and translation, in order to make this technology possible.

72. **Assertion (A):** A terrestrial plant may die if its roots remain waterlogged for a long time.

Reason (R): Terrestrial plants are not used to waterlogging conditions.

73. Consider the following statements:

1. Parboiled or sela rice, on cooking, results in less breakage of the grain. It also retains the important nutrients and can be stored for longer duration.
2. The grain is steamed at high pressure and dried and then the hull is removed by milling.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

74. Consider the following statements:

1. Chocolates cut the risk of strokes. However consumption of dark chocolate is more beneficial than having milk chocolate.
2. Dark chocolate contain more cacao and more sugar.

Which of the statements given above is/are correct?

(a) Both 1 and 2 (b) Neither 1 nor 2
(c) 1 only (d) 2 only

75. Consider the following statements:
   1. Antioxidants play a crucial role in preventing cell damage.
   2. Antioxidants break free radicals that destroy the tissues.

   Which of the statements given above is/are correct?

   (a) Both 1 and 2 (b) 1 only
   (c) 2 only (d) Neither 1 nor 2

76. Consider the following statements:
   1. Drinking a cup of black tea is more injurious than a cup of tea containing milk.
   2. Black tea contains more alkaloids.

   Which of the statements given above is/are correct?

   (a) Both 1 and 2 (b) Neither 1 nor 2
   (c) 1 only (d) 2 only

77. Consider the following statements:
   1. Free radicals are atoms that start a chain reaction and cause damage when they react with important cellular components such as DNA or cell membranes.
   2. Antioxidants activity (AOA) protects the cell from free radicals.

   Which of the statements given above is/are correct?

   (a) Both 1 and 2 (b) Neither 1 nor 2
   (c) 1 only (d) 2 only

78. Consider the following statements:
   1. Raw potatoes cannot be digested by humans.
   2. The starch grains are enclosed in cell wall, therefore the starch is not available for digestion.

   Which of the statements given above is/are correct?

   (a) Both 1 and 2 (b) Neither 1 nor 2
   (c) 1 only (d) 2 only

79. Consider the following statements:
   1. In tissue culture agar is used; which is obtained from algae.
   2. Agar is semisolid at room temperature and does not interfere in the growth of tissue.
   3. Agar is used only in plant tissue culture.

   Which of the statements given above is/are correct?

   (a) 1 and 2 only (b) 2 only
   (c) 1 and 3 only (d) 1, 2 and 3

80. Consider the following statements:
   1. Nuts like almond, pistachio, etc. are preferred in winters.
   2. Nuts are the best source of proteins, fibre and antioxidants.

   Which of the statements given above is/are correct?

   (a) 1 only (b) 1 and 2
   (c) 2 only (d) Neither 1 nor 2

81. Consider the following statements:
   1. Crop rotation adds nutrients to the soil. Legumes are used in crop rotation.
   2. Legumes have root nodules, which contain nitrogen-fixing bacteria, which replenish the soil that has been depleted of nitrogen.

   Which of the statements given above is/are incorrect?

   (a) Neither 1 nor 2 (b) Both 1 and 2
   (c) 2 only (d) 1 only

82. It is best to eat fruits separately, not combined with other foods because
   1. Different food classes require different enzymes, different rates of digestion and different digestive pH for proper digestion
   2. If the fast-digesting foods such as fruits are held up in the digestive system for a longer time than necessary; fermentation takes place and it leads to acidity
   3. Fruits and vegetables require different digestive enzymes, which tend to neutralise each other

4. Fruit's taste is neutralised when taken with other food

Which of the above given statements is/are correct?

(a) 1, 3 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) None of the above

83. What is a false fruit?

(a) An accessory fruit in which some of the flesh is not derived from the ovary but some adjacent tissue exterior to the carpel
(b) A fruit which is formed without fertilisation
(c) A fruit without juice
(d) A fruit formed from the vegetative portion of the plant

*84. Consider the following statements:

1. Sweet orange plant is propagated by grafting technique.
2. Jasmine plant is propagated by layering technique.

Which of the statements given above is/are correct?

(a) Both 1 and 2 (b) 1 only
(c) 2 only (d) Neither 1 nor 2

85. The difference between protoplasm and cytoplasm is

(a) Protoplasm is the whole content of cell enclosed within the cell membrane; cytoplasm is the content of the cell except the nucleus.
(b) There is no difference at all.
(c) Cytoplasm includes all organelles that is in cell except nucleus and protoplasm include the jelly-like substance which doesn't include all the organelles.
(d) Cytoplasm is the soup in which all the other cell organelles reside and protoplasm includes all organelles that is in the cell except nucleus.

86. The plants have vacuoles of different size and composition; the vacuolar sap is also known as

(a) Protoplasm (b) Cell sap
(c) Cytoplasm (d) Karyoplasm

87. Consider the following statements related to difference in mitosis and fission:

1. Binary fission occurs among prokaryotes; mitosis occurs among eukaryotes.
2. Fission does not include spindle formation; mitosis includes spindle formation.
3. Fission is asexual form of reproduction; while mitosis is sexual form of reproduction.
4. Both are asexual form of reproduction.

Which of the above given statements are correct?

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1 and 4

88. The division of nucleoplasm is known as

(a) Karyokinesis (b) Cytokinesis
(c) Nuclear fission (d) Mitosis

89. Who wrote the book entitled *Experiments on Vegetables, Discovering Their Great Power in Purifying the Common Air in Sunshine, but Injuring it in the Shade or at Night*?

(a) Jan Ingenhousz (b) Joseph Black
(c) Joseph Priestley (d) Henry Cavendish

90. What are kelps?

1. Members of red algae having leaf like structure
2. These are large seaweeds belongs to brown algae
3. Clumps of large marine plants and brown algae
4. Large patches of red algae

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) 2 and 3 only (d) 1 and 4 only

91. Which of the following is/are used as food?

1. *Polyporous* 2. *Puccinia*
3. *Podophyllum* 4. *Porphyra*

Select the correct answer using the code given below.

(a) 1 and 2 only (b) 3 and 4 only
(c) 1, 2 and 3 only (d) 4 only

92. The starch produced by red algae is

(a) Amylose (b) Amylopectin
(c) Floridean starch (d) Dextrin starch

93. Which of the followings can produce light?

1. Dinoflagellate 2. Diatoms
3. Red Algae 4. Brown Algae

Select the correct answer using the codes given below.

(a) 1 only (b) 2 only
(c) 3 and 4 only (d) All of the above

94. Which of the followings is/are used for making scouring powder, toothpaste and sugar refining?

1. Diatoms 2. Dinoflagellates
3. *Dioscorea* 4. *Digitalis*

Select the correct answer using the codes given below.

(a) 1 only (b) 2 only
(c) 3 and 4 only (d) All of the above

95. The mermaid's wine glass is common name of which alga?

(a) *Acetabularia* (b) *Ulva*
(c) *Porphyra* (d) *Chalymadomoas*

96. The pigment produced by dinoflagellate is/are

(i) Porphyrin (ii) Rhodopsin
(iii) Luciferin (iv) Phytochromoblin

Select the correct answer using the codes given below.

(a) (i) and (ii) only (b) (i) and (iv) only
(c) (iii) only (d) All of the above

97. The extinction of American elm tree is threatened by which of the followings fungi?

(i) *Cerutostomelh ulmi*
(ii) *Ascodesmis nigricans*
(iii) *Kuehneola uredinis*
(iv) *Ustilago maydis*

Select the correct answer using the codes given below.

(a) (i) only
(b) (i) and (ii) only
(c) (ii), (iii) and (iv) only
(d) None of the above

98. What are morels and truffles?

1. Product of red algae used in cakes and puddings
2. These are the most highly prized edible mushrooms
3. Jellies made from red algae
4. Artificial flavored candies

Which of the above given statements is/are correct?

(a) 1 and 3 only (b) 2 only
(c) None (d) All of the above

99. Why is it better to hang bananas?

(i) They can be easily hanged.
(ii) They reduce the production of ethylene, the fruit ripening hormone.
(iii) They is very delicate so, by hanging damage can be prevented.
(iv) Banana produces large amount of the gaseous hormone (ethylene) and by hanging the gas diffuses in the air; thus ripening is delayed.

Which of the above given statements is/are correct?

(a) (i), (ii) and (iii) only
(b) (ii), (iii) and (iv) only
(c) (iii) only
(d) (iv) only

100. What modification in leaves helps the plant to survive in arid condition?

(i) The plants have smaller leaves; grow compactly and close to the ground.
(ii) The leaves have thick cuticle to prevent evaporation.
(iii) The leaves are covered with hair.
(iv) The presence of sunken stomata help in survival.

Which of the above given statements is/are correct?

(a) (i) and (ii) only
(b) (ii) and (iv) only
(c) (i), (ii) and (iii) only
(d) All of the above.

101. "Maternity plant" or "Mother of thousands" is the common house plant in which the notches on the leaves give rise to small plants. The botanical name of the plant is
(a) *Kalanchoe daigremontiana*
(b) *Aspleinum rhizophyllum*
(c) *Poa pratensis*
(d) *Monstera deliciosa*

102. The process of vegetative reproduction, where the stem is left on the tree till the time adventitious root, develops is
(a) Grafting (b) Pruning
(c) Marcotting (d) Rooting

103. Consider the following statements about virulent strains of micro-organism.
1. Cause infection to produce disease
2. Multiply very fast
3. Are deadly
4. Highly active

Which of the above given statements is/are correct?
(a) 1 only (b) 2 only
(c) 1 and 3 only (d) 2 and 4 only

104. Bioluminiscence is natural process occurs in many marine organisms, as well as microorganisms and terrestrial animals. This is controlled by the production of a pigment and an enzyme called
(a) Luciferin and luciferase
(b) Luciferin and peroxidase
(c) Rhodopsin and luciferase
(d) Lumincin and luciferase

105. Dephlogisticated air means air contains
(i) Oxygen (ii) Carbon dioxide
(iii) Humidity (iv) Pollutants

Select the correct answer using the codes given below.
(a) (i) only (b) (i) and (iv) only
(c) (ii) and (iv) only (d) All of the above

106. Jarovisation means
(a) Cold treatment required for flowering
(b) Cold stratification; a cold treatment used to render seeds capable of germination
(c) Cold storage
(d) Cold weather which induces dormancy

107. Consider the following statements:
1. Sirenin is a chemical attractant secreted by female gametophyte of certain fungi.
2. Allelopathy is plant–plant interaction.
3. Phytotoxins are produced by fungal pathogens.
4. Allomones plays defensive roles in plant-insect and plant-fungal attraction.

Which of the above given statements is/are not true?
(a) Only 1 (b) Only 2
(c) Only 3 (d) None of the above

108. The phenotype of an organism is
(a) The type of specimen of its species is in a museum
(b) Its genetic constitution, which governs its traits
(c) The chronological expression of its gene
(d) The physical expression of its genotype

109. The fitness of genotype is a function of the
(a) Average rates of survival and reproduction of individuals with that of genotype
(b) Individuals that have the highest rates of both survival and reproduction
(c) Individuals that have highest rates of survival
(d) Individuals that have the highest rates of reproduction

110. Speciation is an important component of evolution because it
(a) Generates the variation on which natural selection acts
(b) Generates the variation on which genetic drift and mutations act
(c) Generates the high extinction rates that drive evolutionary change

(d) Has resulted in a world with one millions of species, each adapted for a particular way of life

111. Phylogenetic trees can be constructed for
(a) Genes
(b) Species
(c) Major evolutionary groups
(d) All of the above

112. All carnivorous plants
1. Are parasites
2. Are incapable of photosynthesis
3. Depend on animals as a source of carbon
4. Obtain supplement nitrogen from animals

Which of the above given statements is/are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 3 only (d) 4 only

113. Consider the following plants:
(i) Dodder (ii) Sundew
(iii) Venus fly trap (iv) Pitcher plant

Name the parasitic plant/s using the codes given below.
(a) 1 only (b) 2 only
(c) 1, 2 and 4 (d) All of the above

114. Nitrification is
1. Performed only by plants
2. Performed by certain bacteria in the soil
3. Catalysed by the enzyme nitrogenase
4. The reduction of ammonium ions to nitrates ions

Which of the above given statements is/are correct?
(a) 1 only (b) 2 only
(c) 1, 3 and 4 only (d) None of the above

115. Nitrate reduction
(a) Is known as Haber process
(b) Takes place in mitochondria
(c) Is performed by the plants
(d) Includes the reduction of nitrite ions to nitrate ions

116. Consider the following:
Nitrogen fixation is
1. Performed only by the plants
2. Catalysed by the enzyme nitrogenase
3. A single step chemical reaction
4. The oxidation of nitrogen gas

Which of the statements given above is/are correct?
(a) 1 only (b) 2 only
(c) 2 and 3 only (d) 3 and 4 only

117. Consider the following statements:
(i) Removal of bacteria
(ii) Mechanical weathering
(iii) Clay formation
(iv) Hydrolysis of soil minerals

Which of the above given process is/are not important for soil formation?

Select the correct answer using the codes given below:
(a) (i) only (b) (iv) only
(c) (ii) and (iii) only (d) None of the above

118. Fertilisers
(a) Are often characterised by their N-P-O percentages
(b) Restore needed mineral nutrients
(c) Are needed to destroy soil pests
(d) Provides carbon, hydrogen and oxygen to the plants

119. A typical soil is one in which
(a) There is five or more horizon
(b) The dead and decaying organic matter gathers in the B horizon
(c) The topsoil tends to lose minerals nutrients by leaching
(d) The C horizon consists of primarily of loam

120. Macronutrients are
(a) Required in concentrations of at least 1 gram per kilogram of plant dry matter
(b) So called because they are more essential than micronutrients

(b) Each of its gametes contains one copy of that allele.

(c) It is true breeding with respect to that allele.

(d) Its parents were necessarily homozygous for that allele.

142. The phenotype of an individual

(a) Depends on the genotype and environment interaction

(b) Is either homozygous or heterozygous

(c) Is the genetic constitution of the organism

(d) Determines the genotype

143. The characteristic features of genetic code are:

(i) It is almost universal.

(ii) It is a triplet of nucleotides bases corresponding to 20 amino acids.

(iii) It is non-overlapping, non-ambiguous and comma less.

(iv) It has start and stop codon.

Which of the statements given above are true?

(a) (i), (ii) and (iv) only

(b) (i), (iii) and (iv) only

(c) (i), (ii) and (iii) only

(d) All of the above

144. Errors in transcription occur about 100,000 times, as often as errors do, in DNA replication. How can this high rate be tolerated in RNA synthesis but not in DNA synthesis?

(a) DNA is a master copy of life of the cell and is transmitted to next generation.

(b) RNA is the carbon copy and error in only leads to change in that particular generation and does not affect the future generation.

(c) DNA polymerase is the enzyme which can do its own proof reading and thus there are fewer errors in DNA replication; DNA is the original copy which is transmitted to next generation.

(d) Geneticist is unable to explain the cause.

145. A point mutation is a change, in a single nucleotide in the DNA. How it is possible that sometimes point mutation does not change the protein synthesis?

(a) As there is more than one codon for some amino acid; change in last base in triplet codon has no effect on the protein synthesised in mutant.

(b) If there is a change of one amino acid in protein it does not affect much.

(c) It is not possible that a mutation will not change in the protein.

(d) It is only a chance factor.

146. DNA fingerprinting involves

(i) The variation in repeated sequences between two restriction site is evaluated

(ii) Amplification of DNA

(iii) A gel blotting only

(iv) Multiple restriction enzymes

Select the correct answer using the codes given below.

(a) (i) only (b) (iii) only

(c) (i) and (iv) only (d) (ii) and (iv) only

147. Restriction enzymes are also known as molecular scissors as it

(a) Cleaves DNA at highly specific recognition sequence

(b) Add methyl group to specific DNA sequence

(c) Cut bacterial DNA only

(d) Cut viral DNA only

148. When fragments of DNA are placed in an electric field

(a) The smaller pieces move most rapidly toward the positive pole

(b) The larger pieces move most rapidly towards the positive pole

(c) The large pieces move most rapidly toward the negative pole

(d) The larger and smaller pieces move at the same rate

149. What is the Golden Revolution?

1. The large production of saffron.
2. The patenting of turmeric; it has helped to procure large sum of foreign exchange.
3. The change in economic growth by horticulture and floriculture.
4. The high yield of golden rice.

Which of the above given statements is/are correct?

(a) 1 only (b) 2 only
(c) 3 only (d) All of the above

150. What is "potpourri"?

(a) Dried flowers and painted flowers for decoration purposes.
(b) It is a mixture of natural or artificial fragrant plant material to provide a gentle natural scent in houses.
(c) Dried flowers and plants used in making hand-made paper and other gift items.
(d) Dried plant parts used for packaging and transportation of the breakable items.

151. CTC is a type of processing the black tea. CTC stands for

(a) Crush, Tear and Curl
(b) Cut, Tear and Curl
(c) Crush, Torn and Curve
(d) Curl, Twist and Curve

152. How is filtered coffee processed?

(a) The beans are either freeze-dried or spray-dried and then powdered; it passed through the metal-filter.
(b) It is a made from dark roasted coffee beans and chichory; the powder is passed through a filter made of disposable paper, which removes oily components.
(c) The green coffee beans are fermented and then it is air dried and roasted; a powder of beans is then passed through paper-filters.
(d) The roasted bean powder is passed through metal-filter.

153. Consider the following:

1. Potpourri—Art of growing trees in pots
2. Topiary—Japanese art of paper folding
3. Bonsai—Mixture of dried scented flowers
4. Origami—Japanese art of flower arrangement
5. Ikebana—An art and a form of living sculpture

Which of the above are matched correctly?

(a) 1, 3 and 5 (b) 2, 3 and 4
(c) All of the above (d) None of the above

154. Consider the following statements regarding the benefits of a high- fibre diet.

(i) A high-fibre diet improves regular bowel movements and eliminates toxins.
(ii) It slows digestion, thereby controlling the blood sugar levels.
(iii) It lowers the cholesterol levels, enables easier weight loss and reduced risk of colorectal cancer.

Select the correct answer using the codes given below.

(a) (i) and (ii) only (b) (ii) and (iii) only
(c) (i) and (iii) only (d) All of the above

155. What is the difference between soluble and insoluble fibre?

(i) The fibre which is damaged by treatment with mild acid is soluble fibre and which is not affected by acid treatment is insoluble fibre.
(ii) The plant fibre is insoluble as they have cellulosic cell wall, while animal fibres which are protein in nature are soluble fibre.
(iii) Insoluble fibre does not dissolve in water and soluble fibre does.
(iv) The fibre obtained from stem is insoluble and those obtained from leaves are soluble.

Which of the above given statements is/are correct?

(a) None of the above
(b) (ii) and (iii) only
(c) (iii) only
(d) (iv) only

156. How is it possible to differentiate between plant and animal fibre?

(a) The plant fibre will be hard in texture while animal fibre is soft.

(b) The plant fibre is long and animal fibre is short in length.

(c) The animal fibre is proteinaceous in nature and plant fibre is cellulosic.

(d) Both the fibre smells differently when burnt.

157. How is plant edible fibre different from plant fibre woven into fabric?

(a) Botanically both are same; the edible fibres are both soluble and insoluble type whereas, as textile fibre is of insoluble type.

(b) The textile fibre can be separated in bulk by ginning or retting process.

(c) The textile fibre can be easily woven.

(d) All of the above.

158. Does lemon juice alkalinise the blood?

(a) No, lemons have a low pH (acidic pH).

(b) Yes, the pH of lemon changes during the body metabolic process and they become highly alkaline-forming.

(c) Yes, only when it is taken along with sugar.

(d) The small amount does not change the blood pH.

159. To keep fresh flowers alive for longer duration, it is recommended to make fresh cut at an angle with sharp knife. Why?

(a) The length of the stem is more and to adjust according to pot; the stem at an angle to increase the surface area of absorption.

(b) The cut at an angle helps to increase surface area for water absorption.

(c) Cutting the stem opens the air blocking in the capillaries; using a sharp knife prevents smashing the capillaries; and oblique cut helps to increase the surface area of water absorption.

(d) It does not work for all types of cut flowers.

160. The botanical name of the plant, whose leaves (tendu leaf) are used for making bidi is

(a) *Dalbergia sisso*

(b) *Diospyros melanoxylon*

(c) *Digitalis purpurea*

(d) *Tectona grandis*

161. The great banyan tree, a member of Moraceae family is commonly called 'Bargad'. In Hindu mythology, the banyan tree is considered sacred and is called

(a) "Pilkhan"

(b) "Baramasi"

(c) "Putranjiva"

(d) "Ashwath Vriksha"

162. The common names of *Aloe vera* are

(a) Lily of the desert, Burn plant, Elephant's gall

(b) Arum lily, Fire-flame bush, Elephant's gall

(c) Lily of the desert, Burn plant, Glory lily

(d) Arum lily, Burn plant, Fire-flame bush

163. The plant tissue culture relies on which of the property/ies of a plant cell?

1. Cellular totipotency
2. Autotrophic
3. Cell wall

Select the correct answer using codes given below.

(a) 1 only (b) 2 only

(c) 2 and 3 only (d) 1, 2 and 3

164. Why mushroom and apple turn brown if they are exposed to air?

(a) Both are iron rich fruit.

(b) Pigment turns brown on oxidation.

(c) The enzyme tyrosinase contained in the cell gets oxidized and turns brown.

(d) Ethylene is released due to which the tissue turns brown.

165. Which gas released by onion causes tears in our eyes?

(a) Syn-propanethial-S-oxide

(b) Sulphur dioxide

(c) Ethane

(d) Reverse transcriptase–production of cDNA from mRNA

*191. The Lamarck theory of organic evoultion is known as the theory of

(a) Natural selection
(b) Inheritance of acquired characters
(c) Continuity of acquired characters
(d) Descent with change

*192. In countries where polished rice is the main cereal in their diet, people suffer from

(a) Pellagra (b) Scurvy
(c) Beri-beri (d) Osteomalacia

*193. Which country is called the "sugar bowl of the world"?

(a) Cuba (b) India
(c) Argentina (d) USA

*194. Match the following diseases with the plants affected

A. Black heart 1. Peas
B. Red rot 2. Wheat
C. Karnal bunt 3. Sugarcane
D. Powdery mildew 4. Potatoes

	A	B	C	D
(a)	1	2	4	3
(b)	4	3	2	1
(c)	3	2	1	4
(d)	2	1	3	4

195. In India, during the last decade, the total cultivated land for which one of the following crops has remained more or less stagnant?

(a) Rice (b) Oilseeds
(c) Pulses (d) Sugarcane

*196. Wheat, barley, lemon, orange, rye and pearl millet belong to

(a) Two plant families
(b) Three plant families
(c) Four plant families
(d) The same plant family

*197. Sucrose content in the sugarcane decreases if

(a) High rainfall occurs during the period of growth of the plant
(b) Frost occurs during the period of ripening
(c) There is fluctuation in temperature during the period of growth of the plant
(d) There is high temperature during the time of ripening

*198. Salinisation occurs when the irrigation water accumulated in the soil evaporates, leaving behind salts and minerals. What are the effects of salinisation on the irrigated land?

(a) It greatly increases the crop production.
(b) It makes some soil impermeable.
(c) It raises the water table.
(d) It fills the air spaces in the soil and water.

*199. Other than *Jatropha curcas*, why is *Pongamia pinnata* also considered a good option for the production of bio-diesel in India?

1. *Pongamia pinnata* grows naturally in most of the arid regions of India.
2. The seeds of *Pongamia pinnata* are rich in lipid content of which half is oleic acid.

Which of the statements given above is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

*200. Which feature of some species of blue-green algae helps to promote them as bio-fertilisers?

(a) They convert atmospheric methane into ammonia which can be readily absorbed by the crop plants.
(b) They induce the crop plants to produce the enzymes which help to convert atmospheric nitrogen to nitrates.
(c) They have the mechanism to convert atmospheric nitrogen into a form that the crop plants can absorb readily.
(d) They induce the roots of the crop plants to absorb the soil nitrates in larger quantities.

201. Why is there no duplication of DNA between Meiosis I and Meiosis II?

(a) To produce genetically identical daughter cell

(b) To increase genetic variability
(c) To reduce the chromosome number to haploid in the resulting daughter cell
(d) The chromosomes duplicate twice during meiosis I

202. Why are there more males with colour blindness than females?
(a) The gene for colour blindness is on the Y chromosome.
(b) The recessive gene is usually masked by another X chromosome in females.
(c) Colour blindness is an X-linked dominant trait.
(d) All the sons of an affected male will have the disorder.

203. Which of the following would have the same base sequence in their DNA?
(a) A male parent and his male offspring
(b) Siblings
(c) Identical twins
(d) A female parent and her offspring

204. Which of the following is/are correctly matched?
(i) Ovule—production of pollen
(ii) Vascular cambium—formation of apical meristem
(iii) Xylem—transport of sugars
(iv) Guard cell—regulation of transpiration rate

Select the correct answer using the codes given below.
(a) (i) and (ii) only
(b) (i) and (iii) only
(c) (iii) only
(d) (iv) only

205. Burning of wood produces a cracking sound. Why?
(a) The gases and tar vapours in the wood escape on burning, making a cracking sound.
(b) Xylem elements in the wood make the cracking sound.
(c) The water present in xylem elements makes the cracking sound.
(d) The cells expand on burning and hence they produce a cracking sound.

206. Which properties of water contribute to the upward movement of water in a tree?
1. Evaporation from leaves pulls water upward.
2. Cohesion due to hydrogen bonding helps to hold together the column of water within the cells.
3. Adhesion of the water to cell walls helps resist the downward pull of gravity.
4. The high surface tension of water makes to stretch or break the surface of the liquid.

Which of the above given statements are correct?
(a) 1, 2 and 4
(b) 1 and 4
(c) None of the above
(d) 1, 2 and 3

207. Can two species of genera have the same chromosome number?
(a) No, it is not possible.
(b) Yes, because it not the chromosome number but the genes present on them makes the two species different from each other.
(c) No, they cannot be considered as different species.
(d) No, two species belonging to different two genera can have the same chromosome number.

208. Some species have the same chromosome number, but they are different. How?
(a) There are many other characteristic features which make them different.
(b) The number of chromosome is unrelated to the information contained in them.
(c) During the course of evolution the change has come; it has nothing to do with chromosome number.
(d) The given statement is not true.

209. Why paper money doesn't disintegrate in a washing machine?

1. There is a wax coating on paper.
2. It is not made up of natural raw material.
3. Paper money is made from textile fibre, cotton and linen, which don't dissolve in water.
4. Wood pulp is chemically treated to make special kind of paper.

Which of the above given statements is/are correct?

(a) 1 only (b) 1 and 2 only
(c) 3 only (d) 1 and 4 only

210. The proteins isolated from bacteria, that catalyze specific cleavage of DNA, are known as:

1. Methylating enzymes
2. Restriction endonucleases
3. Telomerases
4. Polymerases

Select the correct answer using the codes given below.

(a) 1 and 2 only (b) 2 only
(c) 3 and 4 only (d) 1, 3 and 4 only

211. The role of restriction enzymes in genetic engineering is

1. The replacement of nucleus
2. Multiplying DNA
3. Breaking the membrane of target cell
4. Cutting DNA at specific sites

Select the correct answer using the codes given below

(a) 1 and 3 only (b) 2 and 4 only
(c) 3 only (d) 4 only

212. The Flavr Savr transgenic tomato was developed by using

(a) Ribozyme (b) Antisense RNA
(c) RNA siliencing (d) Co-suppression

213. Bt gene is isolated from

1. Bacterium 2. Plant
3. Fungi 4. Virus

Select the correct answer using the codes given below.

(a) 1 only (b) 2 only
(c) 1 and 3 only (d) 1 and 4 only

214. Golden Rice is a rich source of

(a) Vitamin C (b) B- carotene
(c) Thiamine (d) Vitamin A

*215. The following are the characteristics of an area in India:

1. Hot and humid climate
2. Annual rainfall 200cm
3. Hill slopes up to an altitude of 1100 meters
4. Annual range of temperature 15°C to 30°C

Which among the following crops are you most likely to find in the area described above?

(a) Mustard (b) Cotton
(c) Pepper (d) Virginia tobacco

216. The first sequenced genome belongs to

(a) *Escherichia coli.*
(b) *Haemophilus influenzae.*
(c) *Mycoplasma genitalium.*
(d) *Saccharomyces cerevisiae.*

217. The recently developed "Gene Knockout" technology is

(a) A functional gene is inserted in addition the mutant copy
(b) A functional gene is replaced by a mutant copy
(c) A gene is inserted by recombination
(d) A mutant gene is replaced by a functional gene

218. It is easy to produce transgenic plants as compared to transgenic animals because

(a) Plant cell shows cellular totipotency
(b) Animal cell cannot grow in culture
(c) There are no ethical problems with transgenic plants production
(d) The plant cell has cell wall

*219. Regular intake of fruits and vegetables is recommended in the diet since they are a good source of antioxidants. How do antioxidants help a person to maintain health and promote longevity?

(iii) There is an apprehension that the consumption of Bt brinjal may have the adverse impact on health.

(iv) There is some concern that the introduction of Bt brinjal may have an adverse effect on the biodiversity.

Select the correct answer using the codes given below.

(a) (i), (ii) and (iii) only
(b) (ii) and (iii) only
(c) (iii) and (iv) only
(d) (i), (ii), (iii) and (iv)

*228. Other than resistance to pests, what are the prospects for which genetically engineered plants have been created?

1. To enable them to withstand drought
2. To increase the nutritive value of the produce
3. To enable them to grow and do photosynthesis in spaceships and space stations
4. To increase their shelf life

Select the correct answer using the codes given below.

(a) 1 and 2 only (b) 3 and 4 only
(c) 1, 2 and 4 only (d) 1, 2, 3 and 4

ANSWER KEY

1	(d)	2	(c)	3	(a)	4	(b)	5	(d)	6	(c)
7	(a)	8	(c)	9	(b)	10	(a)	11	(d)	12	(c)
13	(a)	14	(a)	15	(c)	16	(b)	17	(c)	18	(d)
19	(d)	20	(b)	21	(b)	22	(a)	23	(b)	24	(d)
25	(c)	26	(b)	27	(a)	28	(a)	29	(a)	30	(a)
31	(b)	32	(d)	33	(d)	34	(c)	35	(a)	36	(d)
37	(b)	38	(d)	39	(d)	40	(d)	41	(b)	42	(a)
43	(b)	44	(b)	45	(c)	46	(c)	47	(a)	48	(d)
49	(a)	50	(c)	51	(a)	52	(c)	53	(c)	54	(b)
55	(c)	56	(a)	57	(b)	58	(d)	59	(b)	60	(c)
61	(b)	62	(a)	63	(a)	64	(b)	65	(b)	66	(c)
67	(c)	68	(a)	69	(b)	70	(a)	71	(a)	72	(b)
73	(a)	74	(c)	75	(a)	76	(d)	77	(a)	78	(a)
79	(a)	80	(b)	81	(a)	82	(b)	83	(a)	84	(b)
85	(a)	86	(b)	87	(b)	88	(a)	89	(a)	90	(b)
91	(d)	92	(c)	93	(a)	94	(b)	95	(a)	96	(c)
97	(a)	98	(b)	99	(d)	100	(d)	101	(a)	102	(c)
103	(a)	104	(a)	105	(a)	106	(b)	107	(d)	108	(d)
109	(d)	110	(d)	111	(d)	112	(d)	113	(a)	114	(b)
115	(c)	116	(b)	117	(a)	118	(b)	119	(c)	120	(a)
121	(a)	122	(a)	123	(a)	124	(a)	125	(a)	126	(d)
127	(c)	128	(c)	129	(b)	130	(d)	131	(b)	132	(a)
133	(b)	134	(a)	135	(c)	136	(d)	137	(c)	138	(b)
139	(d)	140	(c)	141	(d)	142	(a)	143	(d)	144	(b)
145	(a)	146	(a)	147	(a)	148	(a)	149	(c)	150	(b)

151 (a)	152 (b)	153 (d)	154 (d)	155 (c)	156 (c)
157 (d)	158 (b)	159 (c)	160 (b)	161 (d)	162 (a)
163 (a)	164 (c)	165 (a)	166 (d)	167 (b)	168 (a)
169 (c)	170 (d)	171 (d)	172 (c)	173 (a)	174 (b)
175 (b)	176 (b)	177 (a)	178 (a)	179 (b)	180 (d)
181 (a)	182 (d)	183 (a)	184 (b)	185 (b)	186. (b)
187 (a)	188 (c)	189 (a)	190 (b)	191 (b)	192 (c)
193 (a)	194 (b)	195 (c)	196 (a)	197 (d)	198 (b)
199 (c)	200 (c)	201 (a)	202 (b)	203 (c)	204 (d)
205 (a)	206 (d)	207 (b)	208 (b)	209 (c)	210 (b)
211 (d)	212 (b)	213 (a)	214 (b)	215 (c)	216 (b)
217 (b)	218 (a)	219 (c)	220 (c)	221 (b)	222 (b)
223 (d)	224 (d)	225 (d)	226 (b)	227 (b)	228 (c)